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APPLICATION OF ERTS-1 IMAGERY TO STATE-WIDE LAND INFORMATION SYSTEM IN MINNESOTA

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16. Abstract

The utility of ERTS-1 imagery for land based resources information has been demonstrated in several types of investigations in Minesota. Multi season ERTS-1 imagery, when coupled with good topographic maps, has proven extremely valuable for inventory of surface water resources and analysis of seasonal dynamics. The quality of water maps produced far exceeds that of any existing surface water data sources for the state. Spring images have proven useful for low cost analysis of cover free land carried through winter. Land use mapping in the Minneapolis-St. Paul Metropolitan area and Itasca County demonstrate the potential for low cost land use surveys, provided the mapping unit size and land use class definitions with high levels of accuracy meet the imposed data requirements.

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ERTS-1 CAPABILITIES FOR LAND USE MAPPING IN MINNESOTTA

Dwight Brown

Introduction

The Minnesota State Planning Agency (MSPA) and the Center for Urban and Regional Affairs, The University of Minnesota (CURA) have engaged in a cooperative effort to evaluate ERTS-1 imagery for land use information in Minnesota. Specifically the effort has been directed toward examining ERTS-1 imagery as a possible source for updating and improving land use, land cover, and resource condition information for the Minnesota Land Management Information System (MLMIS). Ideally, the objectives of research of this type reach beyond the evaluation of information quality and development of data extraction techniques. The demonstration of the application of data derived from ERTS images to the on-going planning and research operations of various resource management agencies in the state has occupied researchers during the last 12 months of this project. A final objective, for the next research period is the transfer of technology to state and regional planning and resource management agencies where developed applications have been demonstrated to be useful.

This report summarizes the work directed toward the first three objectives in the period from July 1, 1972 - September 23, 1974. Work on the basic evaluation of ERTS-1 imagery and development of data extraction techniques was carried out at the University of Minnesota in the Departments of Forest Resources Development, Geography, and Soil Science. The effort at the University of Minnesota coordinated through the Center for Urban and Regional Affairs with the support and cooperation of the Minnesota Land Management Information System staff.

The research program was divided into the major land use categories already employed by MLMIS, which included cultivated land, forest, open and pasture, marsh and water, extractive industry, urban commercial-

industrial, and urban residential. The utility of ERTS-1 imagery was examined for each of these uses to determine and evaluate data extraction techniques, suitable classification schemes, and data cost information. To support this evaluation effort considerable "ground truth" information was collected from NASA underflight aerial photography, other aerial photography, existing maps and field investigation. These data were also shared with Honeywell to support their digital analysis of ERTS data in Minnesota.

Following the development and evaluation phase several demonstration - quasi operational projects were established based on discussions with and the cooperation and guidance of personnel from the Minnesota Department of Natural Resources (MDNR), the Minnesota State Highway Department (MHD), the Twin Cities Metropolitan Council, and a number of county, local, and private resource managers (Sizer and Brown, 1974).

Four demonstration projects were developed to encompass a variety of land use and land resource planning and management problems. These are: Land Cover in Itasca County, Twin Cities Metropolitan Area Land Use, Wildlife Habitat Change and Seasonal Cultivation, and Seasonal Change in Open Water.

These four demonstration projects provide the basis for exploring the utility of ERTS-1 images for updating land use information in MLMIS. Accuracy of interpretation, utility of the operational definitions of classes, cost of interpretation and conversion to the 40 acre data cell format are the considerations to be made by MLMIS personnel when the system is updated.

Although each of the four projects has some unique characteristics, all produce maps of land cover types that are not interpretations of 40 acre data cells and must be converted to this format to be compatible with the data presently in MLMIS. Development and evaluation of this procedure could best be accomplished by working with only one of the two broader based interpretation projects, Itasca County and the Twin Cities Metropolitan Area. Itasca County was selected for two reasons. It was the first of the demonstration projects to be initiated and it was the only area that already contained a wealth of resource information in MLMIS.

A series of soils, water orientation, forest types and 1969 land use maps can be produced by MLMIS for comparison with ERTS-1 data converted to the 40 acre cell format. It is possible to manipulate the data for analysis of land use by ownership classes or by soil type and to examine land use change to the degree that class definitions are compatible through time (Sizer and Brown, 1974).

It is expected that in 1975 some regional research problems will necessitate the updating of MLMIS information with ERTS. The exact information to be updated or included, however, will be defined locally by planners and resource managers from the state's thirteen planning regions.

This report will include a summary and discussion of the results of land use applications, the Land Cover in Itasca County, and separate chapters on each of the three demonstration projects not included in earlier reports. The products of these three projects are currently being evaluated by personnel from the Twin Cities Metropolitan Council, MDNR, MSPA, and the U.S. Fish and Wildlife Service.

Review and Summary of ERTS-1 Land Use Mapping in Minnesota

The initial objective of this cooperative research project was to evaluate ERTS-1 imagery as a data source for updating the Minnesota Land Management Information System. This goal was accomplished by dividing the research into six broad areas of land use employed by MLMIS. The nine class, level I land use classes used by MLMIS were grouped to facilitate the research organization. These were water, vegetated wetlands, cultivated and open land, forest, extractive, and urban. Table 1 shows the three level land use scheme that was developed as a basis for evaluating ERTS-1 imagery. The accuracy of identification for each class is included in table 1. Most of these figures are based on imagery acquired during the fall of 1972 and winter of 1972/1973. In some instances subsequent images have been received that appear to have better discrimination of some features than the images used for the tests.

TABLE 1

Classes of Land Surface Cover[1]

Level I	Level II	Level III
Extractive (99)	Iron Mining (77)	Tailing Piles (79) Stripping Piles (70) Pits (77)
	Gravel (80) Rock (*) Sanitary Landfill (*)	
Urban (82, 85)	Residential (78, 79)	Older/high density Newer/moderate density
	Commercial/Industrial/ Institutional (74,100)	Commercial Core Outlying nodes & strips
Water (94)[2]	Lakes	Natural Basin Excavated Basin
	Rivers	
Vegetated Wetlands[3] (0-10)	Northern perennial peatlands Southern perennial Seasonal wetlands	
Forests (63-97)	Conifer (12-80) Hardwood (50-56) Mixed (6-54)	
Cultivated (*,95)		

Open and Other (non-cultivated farmland, pasture, open non-farmland, and bare rock or soil) (49-72)

[1]The first number in parentheses gives accuracy of class assignments for each class based on one date of imagery. If the accuracy was highly variable over the study areas a range is given. The second number indicates the accuracy level where multiple dates were used. An asterisk indicates that the frequency of occurance in the test areas was insufficient for adequate evaluation.

[2]The sample here is small and because these features are so dynamic the validity of the base line data is questionable. Accuracy is probably higher than indicated.

[3]The sample is small and biased away from the most easily identified patterned peatlands. Significant confusion exists between these areas and mixed forests and the open and other category.

The nature of Minnesota forests is a powerful contributor to the results obtained from the low resolution small scale ERTS-1 imagery system. Minnesota lies astride a narrow transition zone from the prairie through hardwood and pine forests to the boreal forests. These biomes are not sharply defined. They are complicated by topography, hydrology, and soil patterns, by disease and burn patterns in the forests, and by human alterations of the forest cover. The result is an almost complete lack of uniform density monospecific stands. The dominance of complex forest types yields a wide but nonquantified range of variations in the mix of species for the 10 acre mapping units used in forest type interpretation tests.

A variety of interpreters, image manipulation, techniques, and image dates have been used to develop the statistics included in earlier reports and summarized here. Accuracy of interpretation does vary among operators. However, discipline specialists tend to be more accurate in the interpretation of the subject of their own field than other subjects. The important variations from one broad class to another are dominantly a function of the lack of contrast of some classes or sub-classes with their surrounding land uses. Some of this problem arises from the limited seasonal coverage available at the time of analysis. To a lesser extent accuracy may be a function of the image manipulation and interpretation procedures. Variations in the skill and experience of the interpreters involved seems to bear very little resemblance to the patterns of accuracy.

Procedures Employed in Manual Interpretation

Three types of images have been used in the interpretation of land use: 70mm bulk positive transparencies of individual bands, 2" x 2" slides of custom color combined images, and 2" x 2" slides of standard NASA 9.5" bulk color transparencies. These products are interpreted by direct projection onto a wall mounted base map or by use of a rear projection light table (see Eller, Meyer, and Ulliman, 1973). Interpretation scales range from 1:250,000 to 1:24,000. However, 1:125,000 has been the dominant scale for land use mapping.

Itasca County Land Cover Mapping

Itasca County was selected as a test area because it satisfied several needs that could not be met by other full scale systems test areas. The existance of important forest and iron resources in the southern 1/3 of the county complimented the other demonstration projects. Strong local interest in land based resource information on the part of planners and resource managers was also an important consideration in the selection of Itasca County.

The initial phase of the Itasca County project was the selection of a suitable test area to work out the problems that arise when first integrating operational definitions for different land use classes derived independently. The selected test area included 28 regular and 8 irregular townships in the southeastern part of the county. This area covers just over one third of the county and includes the widest variety of land use classes. (Figure 1)

The land use mapping was carried out as follows:

1. Analysis of imagery to determine which dates, bands, and multi-spectral or multi-seasonal color combined images are best. While this problem may seem to have been solved in earlier work, it must be remembered that some techniques were developed in different locations, and available imagery is neither all of the same date nor all of the same quality. Furthermore, the image inventory is continually expanding to include new time periods.
2. Towns outside of the Mesabi Iron Range area were mapped from projected band 7 bulk MSS 70mm film positives for January 5, 1973. This image was used to maximize the snow enhancement of shadows. This step took one half hour.
3. Mine features and mine area towns were mapped from multi-season color combined slides for October 7, 1972 and January 5, 1973. Four and one half man hours were required.
4. Forest types, open areas, and wetlands were mapped from October 7, 1972 color combined slides. This phase required 12 man hours.

5. Surface water was mapped from projected Band 6, Bulk MSS 70mm positive imagery for October 7, 1972 and required 2 man hours.
6. Because the forest interpretation was mapped independently in the Institute of Agriculture Remote Sensing Laboratory and the towns, extractive and water were mapped in the MLMIS laboratory, it was necessary to adjust discrepancies, gaps and overlaps in information. This step took about 1/2 hour on the part of 3 men or 1.5 man hours.

Complete interpretation and mapping time was 20.5 man hours for an area of more than 1100 square miles. To compare the ERTS derived information with the cost of producing the existing MLMIS data it is necessary to carry the work one step further to the data coding for computer entry. This step has been carried out for two townships and required 1.5 man hours. Considering the relative complexity of the townships estimated coding time for the 1/3 county test area would be 15 man hours.

The MLMIS high altitude panchromatic photo interpretation and coding time are reported in clock hours for work teams of two or three men. Coding was done directly from interpreters calls so no intermediate map was produced. If we can assume an average of 2.5 men in the team, the cost in man hours would be 37.8 man hours as opposed to 35.5 projected from ERTS-1. While very close, these figures can be quite misleading. A number of very important non-quantifiable differences exist.

1. The detail of data extracted from ERTS was much greater. Forests were broken down into 4 classes with ERTS, where only one was used in the original MLMIS base. Three kinds of water features were identified on ERTS and only one in MLMIS. Three kinds of mine features were identified on ERTS as opposed to one from the MLMIS.
2. It is feasible to incorporate several seasons of monoscopic, multi-spectral coverage with ERTS whereas only one season (leaf off spring) of stereoscopic, panchromatic photography was available for the MLMIS work. Thus the technologies are not comparable.

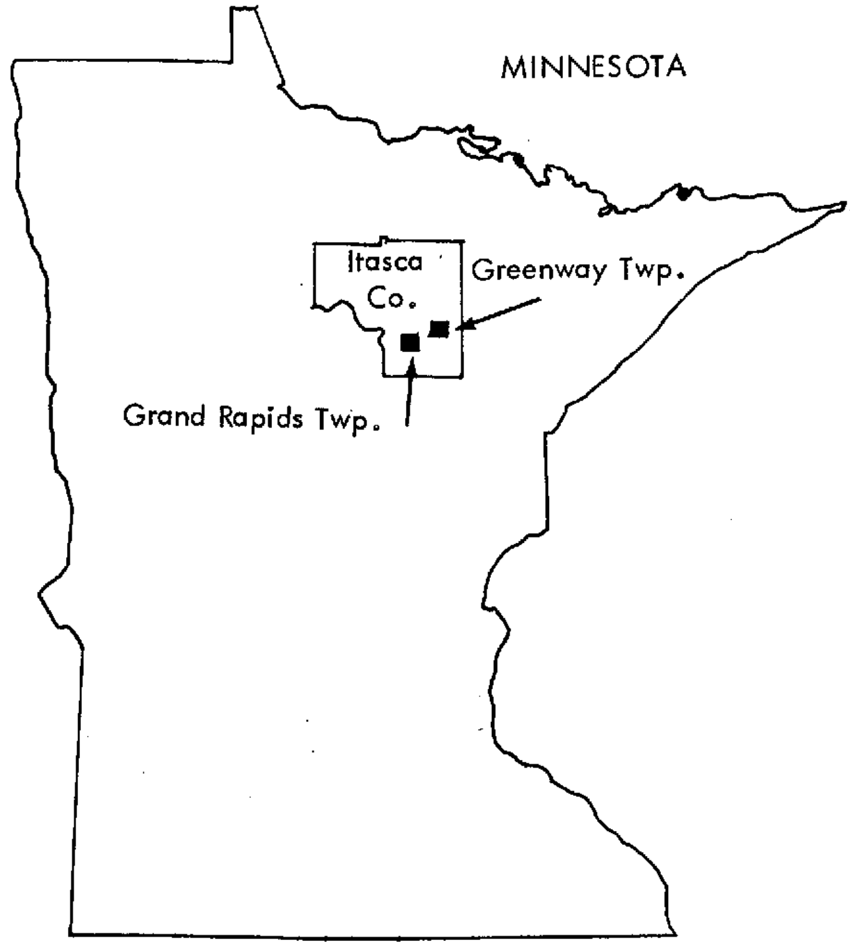


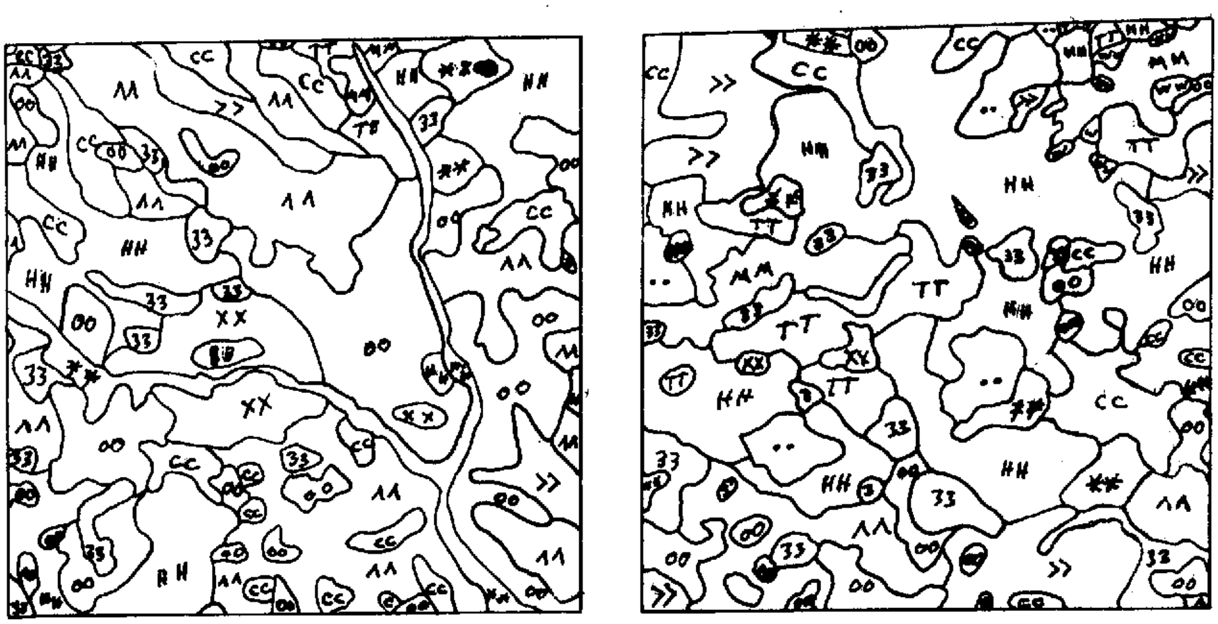
Figure 1. Location of the Itasca County study area.

3. An estimated four man hours reduction in interpretation time could be achieved if the work was done by one interpreter and lakes were mapped first. This of course implies that the interpreter has a very broad range of experience. Thus more training and higher cost personnel of uncertain availability would be needed. At this stage a multi discipline team approach still seems to be the best solution despite the slight time disadvantage.

Transferring this preliminary mapping experience from Itasca County to other counties in Minnesota is difficult. Most of the state has fewer land use classes and simpler texture of land use patterns, thus easing the coding process. Coding time is also relatively longer in Itasca County because of irregularities in the public land survey. Both of these problems presumably also apply to the original MLMIS land use interpretations.

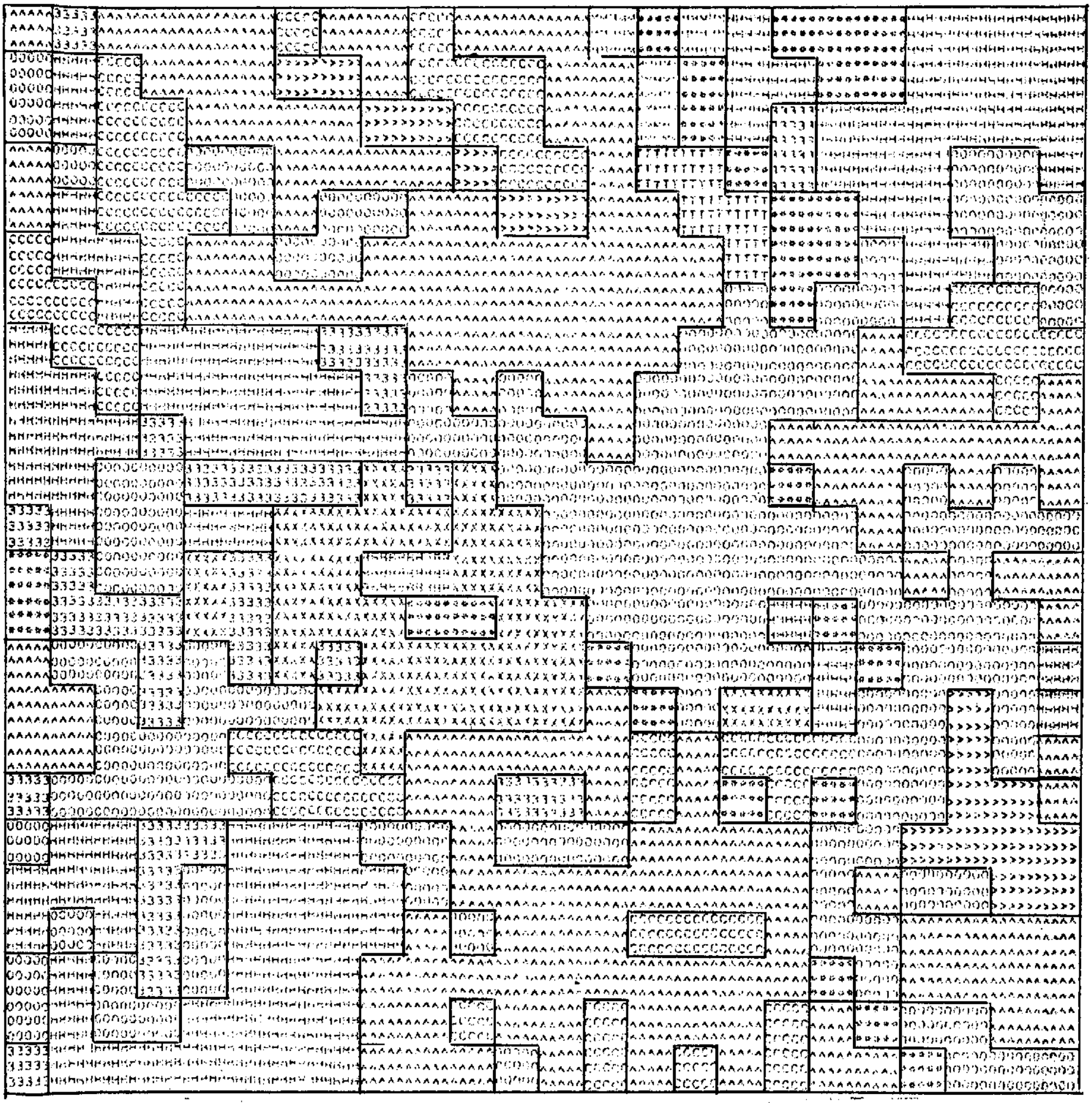
As part of the test two townships were coded for debugging the CRT display keyboard entry and edit system for MLMIS updating. The main technical problem, expanding the number of classes of land use, required only a minor program change. Figures 2, 3, and 4 are examples of the preliminary maps and computer printout for two townships after the data are coded, entered, and edited on the CRT display.

Independently an evaluation of the quality and utility of the map for forest land managers was carried out by Ralph G. Eller and Joseph



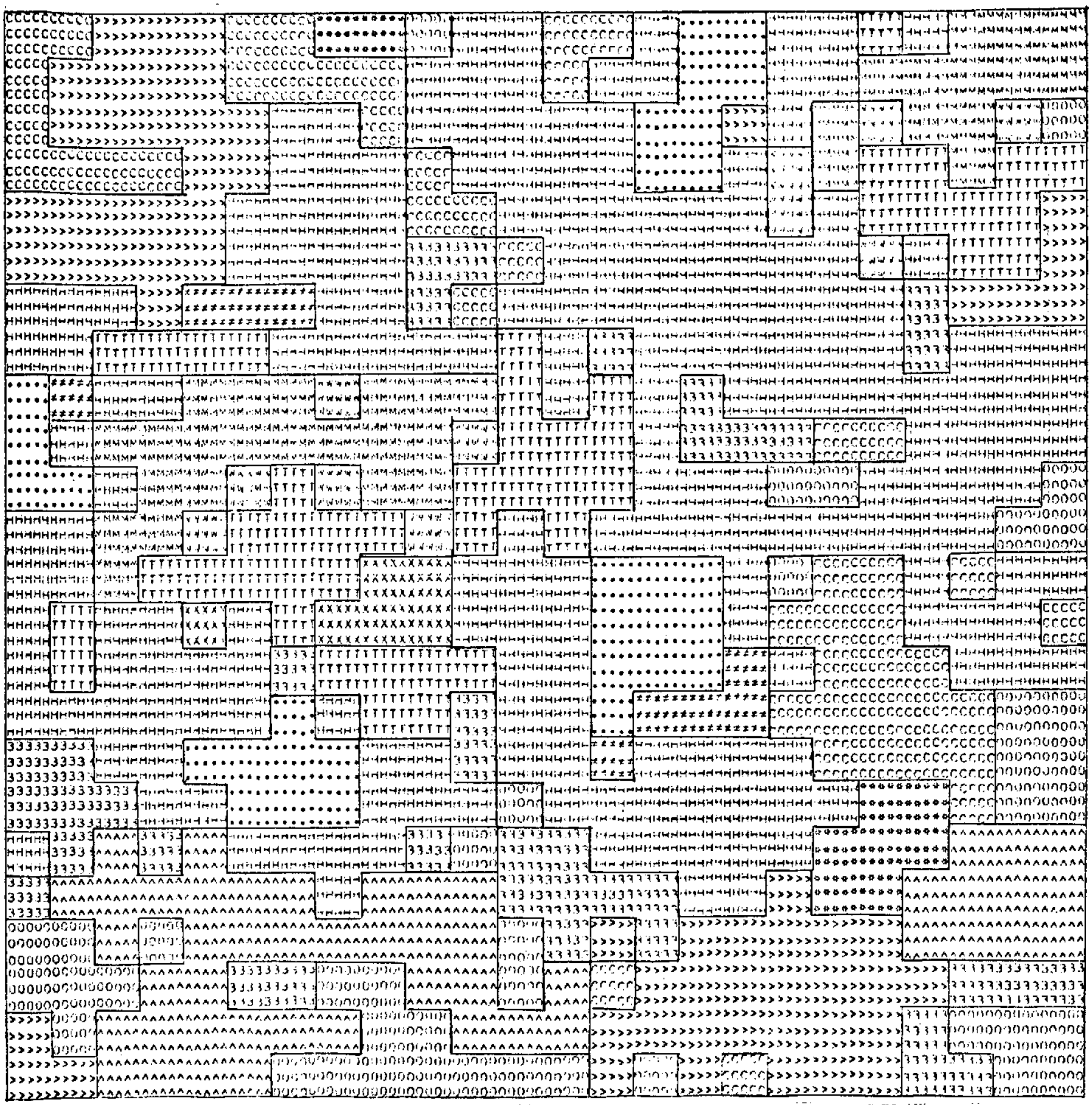
Grand Rapids Township   Greenway Township

Figure 2. ERTS-1 based land use interpretations for Grand Rapids and Greenway Townships. Legend is the same as Figures 3 and 4.



LAND USE SYMBOLS	CODE	LAND USE SYMBOLS	CODE
00 =	OPEN/CULTIVATED	33 =	WATER
** =	WETLANDS	... =	HARDWOODS
CC =	CONIFERS	XX =	URBAN
HH =	CBD	^^ =	MIXED/HARDWOODS DOMINANT
>> =	MIXED/CONIFERS DOMINANT	-- =	MINES
TT =	TAILINGS PILES	** =	TAILINGS BASINS
## =	WATER FILLED PITS	## =	TAILINGS PONDS

Figure 3. Computer print out of ERTS-1 based land use map of Grand Rapids Township coded for forty acre cells.



LAND USE SYMBOLS		CODE	LAND USE SYMBOLS		CODE
OO	=	OPEN/CULTIVATED	33	=	WATER
**	=	WETLANDS	HH	=	HARDWOODS
CC	=	CONIFERS	XX	=	URBAN
##	=	CBD	AA	=	MIXED/HARDWOODS DOMINANT
>>	=	MIXED/CONIFERS DOMINANT	MM	=	MINES
TT	=	TAILINGS PILES	..	=	TAILINGS BASINS
##	=	WATER FILLED PITS	**	=	TAILINGS PONDS

Figure 4. Computer print out of ERTS-1 based land use map of Greenway Township coded for forty acre cells.

J. Ulliman (1974). The study, based on color combined band ERTS-1, multi date color combined and black and white imagery, included forest types and involved Itasca County test sites as well as others in the state. Their results show a significant improvement in the detectability of hardwoods in all cases; but, conifer detection was generally below 50%. Their evaluation indicated that at the forest land managers level the accuracy and detail attained to date are insufficient to produce a map for use in local forest management.

While the quality of information extractable from ERTS-1 images is disappointing from the forest managers' point of view, it should be noted that the general level of accuracy at Level I as shown in Table 1 is generally quite good and that extractive and urban classes can be examined in more detail without severe drops in accuracy of class assignments. The utility of Level II and Level III information at the accuracy attained in this study is highly dependent on the quality of information already available to planners and resource managers at the regional or state level. If the quality of ERTS-1 derived information is higher than existing data, by either the nature or age of the data, then the ERTS system can be a useful tool for extraction of low cost data in the interum period. Its utility may also be increased when it is used as a check for significant change in an existing and highly detailed data base if the phenonema being mapped are several resolution elements in size.

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Wildlife Habitat Change and Seasonal Cultivation

Dwight A. Brown[1], John A. Harrington[2], Tom Isley[3], John M. Smiley[1], Dave Soehren[3], Eliahu Stern[1]

In response to the expressed needs of Minnesota Department of Natural Resources (MDNR) game biologists, a cooperative project was established to evaluate the application of ERTS-1 derived seasonal cultivation maps to wildlife habitat planning and management.

The wildlife habitat study evolved from agricultural land use investigations that used a monitoring and aggregation system, to obtain an accurate inventory of cultivated land from ERTS-1 images (Graber et al. 1973 pp. 18-23). The intermediate stage maps were examined by game biologists in MDNR, who determined that this periodic-type of information was useful in planning wildlife habitat programs. As a result, a demonstration project was established that encompassed seven townships in West-Central Minnesota. The following is a description of the methods, results, and comparative cost estimates of this study.

Procedures

The test sites were selected by MDNR regional game biologists based at Madelia, Minnesota. Fortunately, the seven townships selected in Traverse, Grant, and Wilkin Counties are located in the coverage overlap area of two orbital paths, thus maximizing the probability of regular cloud free coverage (Figure 1). All seven townships are located on the flat Pleistocene Lake Agassiz Plain, where cultivated farmland exceeds 95% of the total land area of most townships. Field sizes are larger than the average for Minnesota. Because of the variety of small grains, sugar beets, corn, and soybeans grown, the time of cultivation and the length of the vegetation-free surface varies considerably within the study area.

Interpretation of plowing in the first study area (Fig. 1) was accomplished by projecting ERTS-1 bulk 70mm band 7 positive transparencies onto 1:125,000 scale wall mounted maps with a

[1]Dept. of Geog.,Univ. of Minn., Mpls., Minn; [2]Dept. of Geog., Mich. State, East Lansing; [3]Minn. Dept. of Natural Resources

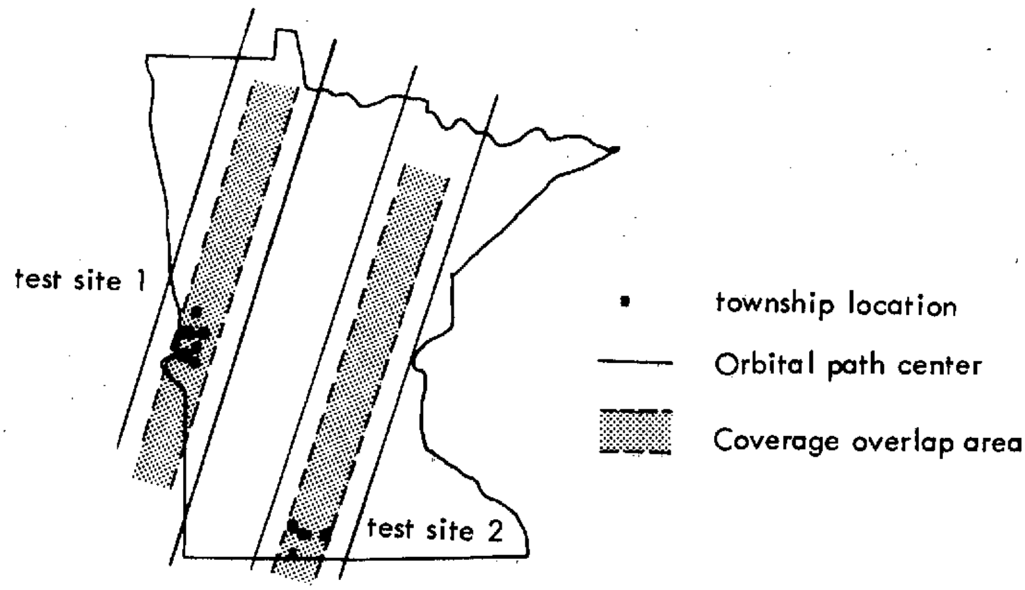


FIGURE 1 - Location of test sites

lantern slide projector. Freshly plowed fields, which appear black, and recently plowed fields, which appear dark grey, are delineated for each period of coverage. Originally, only the black, freshly plowed fields were mapped, resulting in the loss of information on fields cultivated immediately following the previous coverage period. These fields were found to weather, to be smoothed by rain, and to dry, yielding an increase in the reflectance in the near infrared.

Results

Figures 2 and 3 show the mapping results for one township for ten time periods from August 16, 1972 to October 9, 1973. Fields that showed definite signs of cultivation were grouped with "possibly plowed" fields. In the next phase of mapping "plowed" and "possibly plowed" were separated for all seven townships. Maps for the seven townships for each of nine time periods are shown in Figures 4-12.

Although the MDNR game biologists recognized some applications

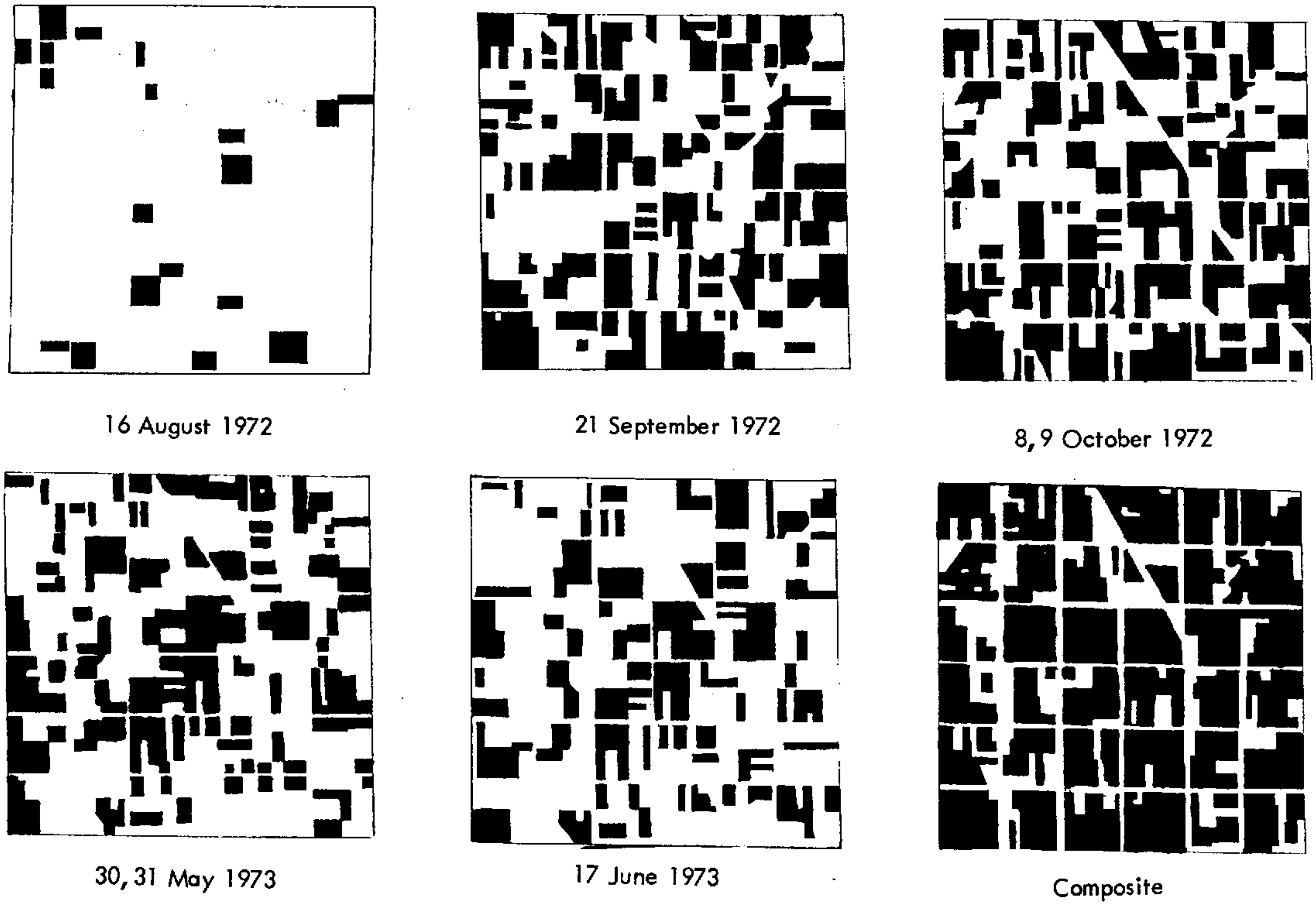


FIGURE 2 - Bare, plowed fields for five dates and composite map for Croke Township, Traverse County, Minnesota. August, 1972 - June, 1973.

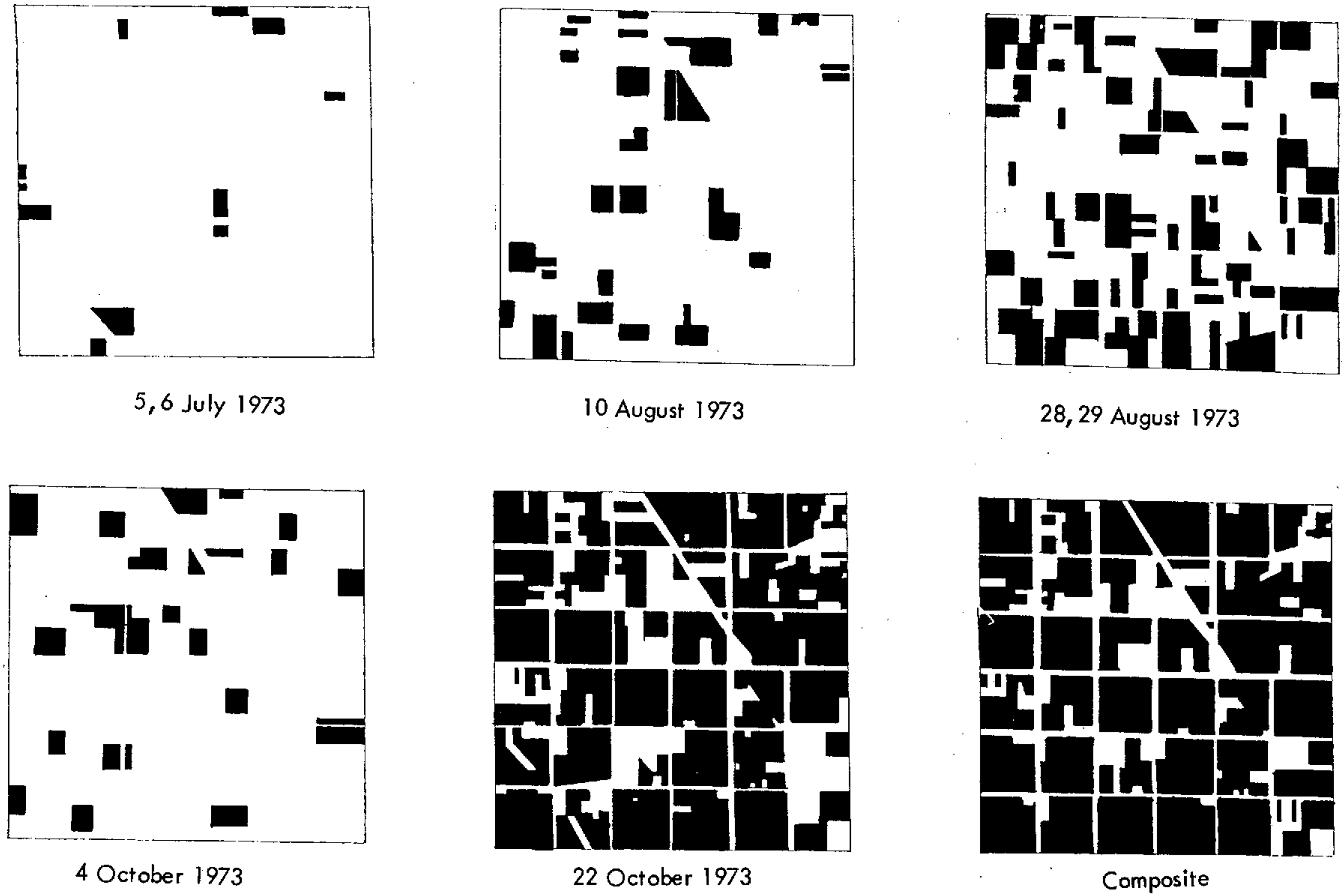


FIGURE 3 - Bare, plowed fields for five dates and composite map for Croke Township, Traverse County, Minnesota. July through October, 1973.

FIGURE 4 - Plowed fields - West Central Minnesota, August 16, 1972
from ERTS - 1 Image 1024-16484 Scale - 1 : 205,000
Plowed Field   Possibly Plowed Field

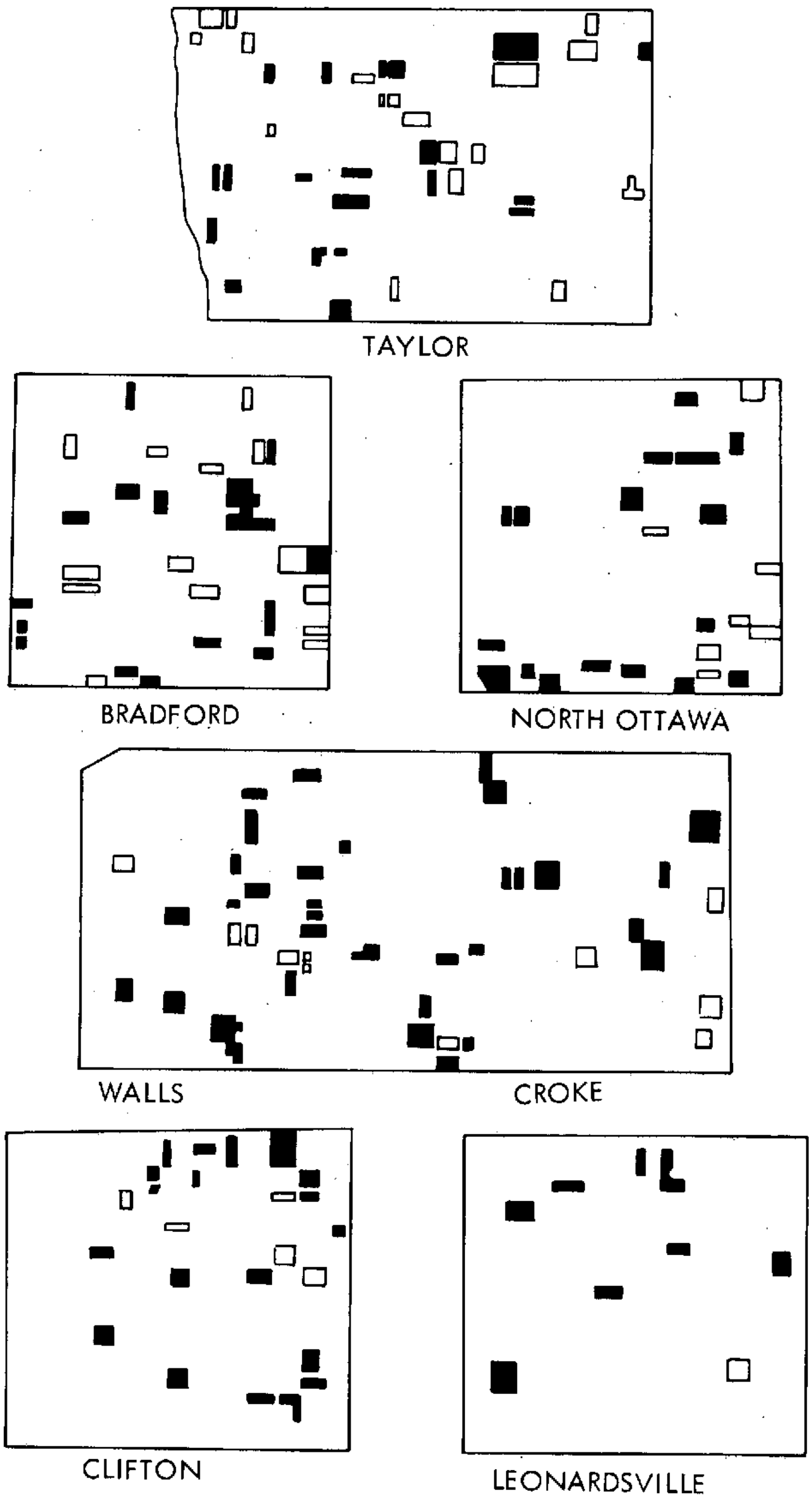


FIGURE 5 - Plowed fields - West Central Minnesota, September 21, 1972
from ERTS - 1 Image 1060-16485 Scale 1 : 205,000

FIGURE 6 - Plowed fields - West Central Minnesota, October 8 and 9, 1972
from ERTS - 1 Image 1077-16431 Scale - 1 : 205,000

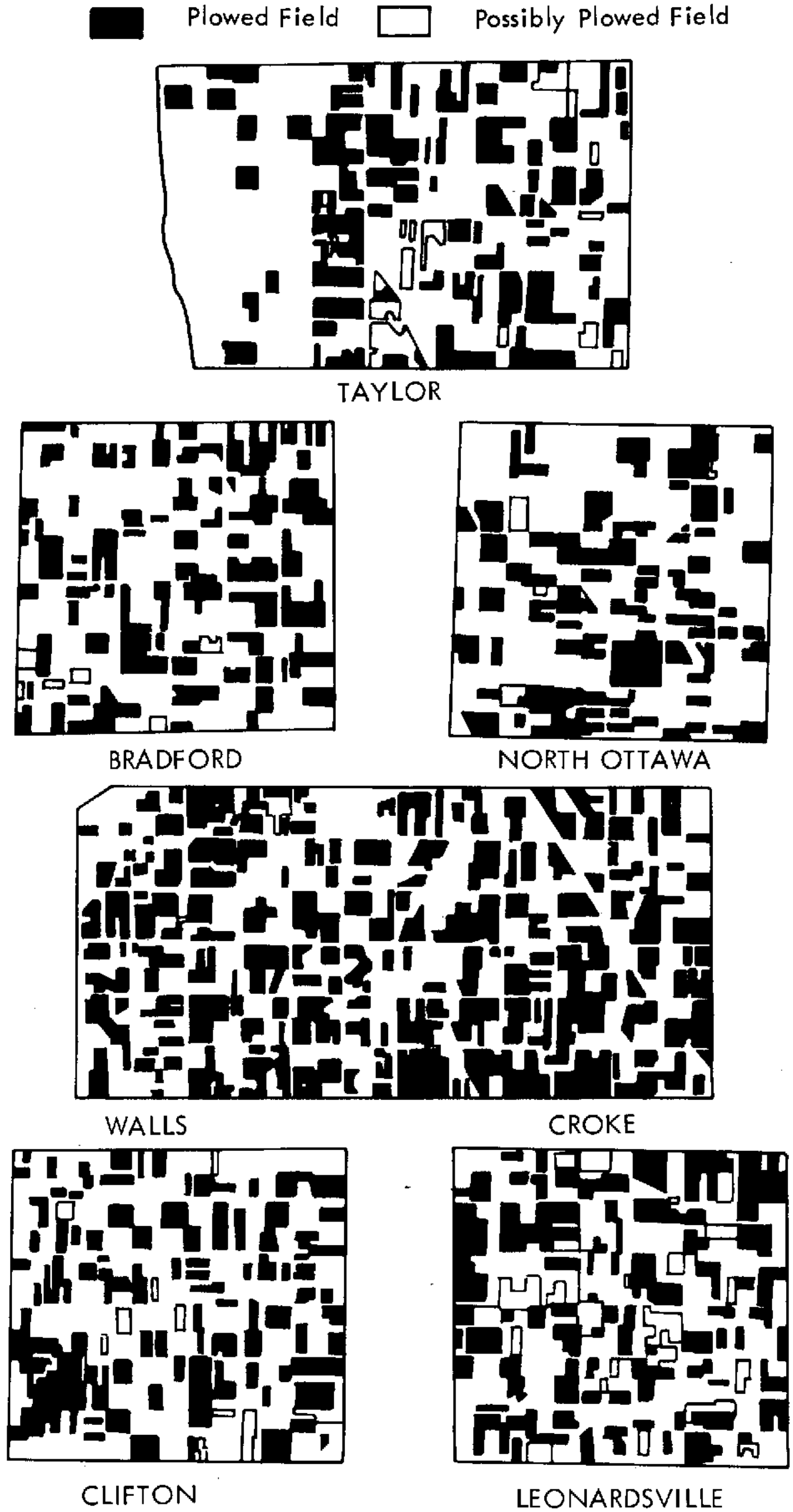


FIGURE 7 - Plowed fields - West Central Minnesota, May 30 and 31, 1973 from ERTS - 1 Images 1311-16435 & 1312-16493 Scale 1 : 205,000

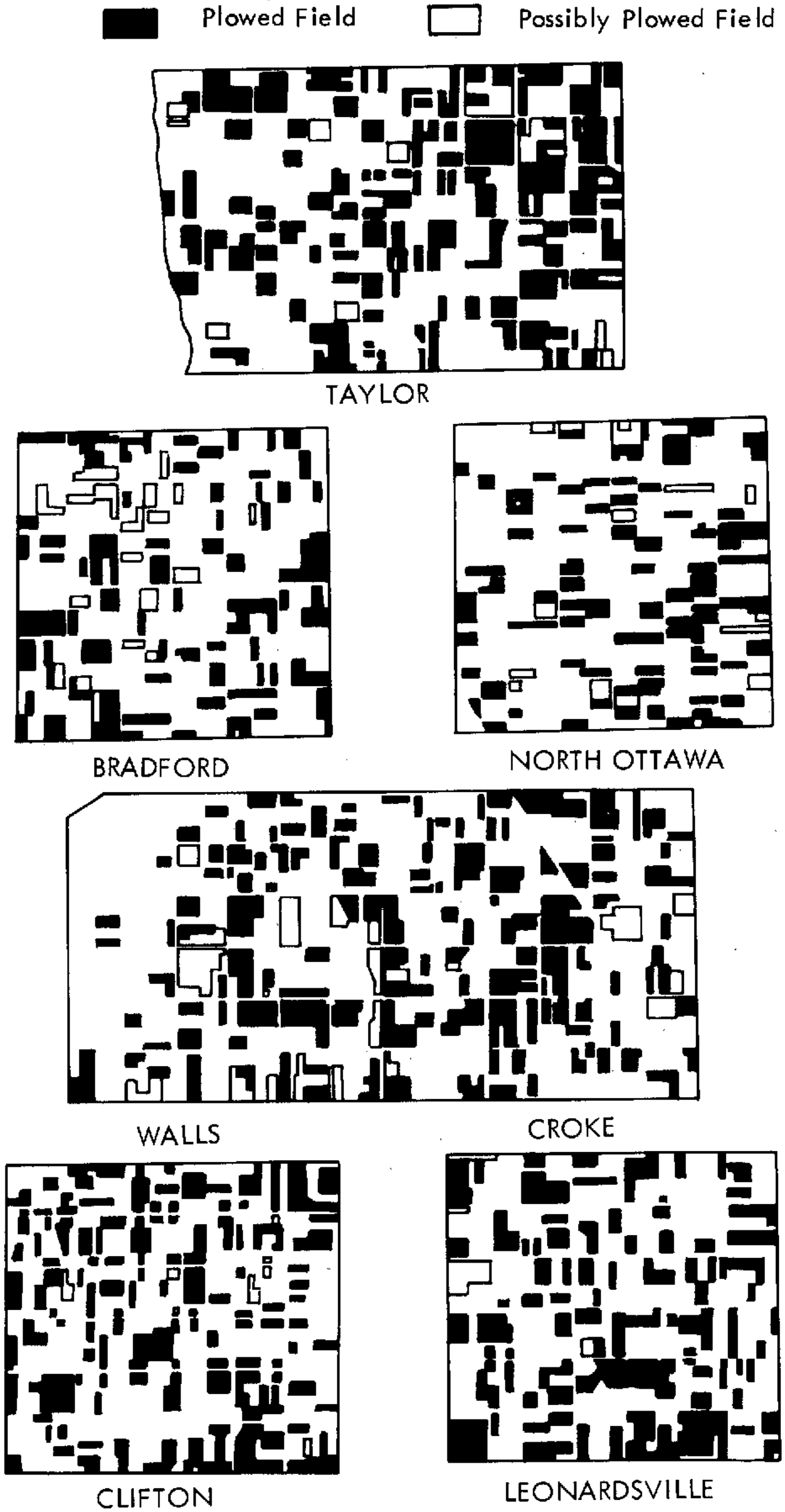


FIGURE 8 – Plowed fields – West Central Minnesota, June 17, 1973
from ERTS – 1 Image 1329-16434 Scale 1 : 205,000

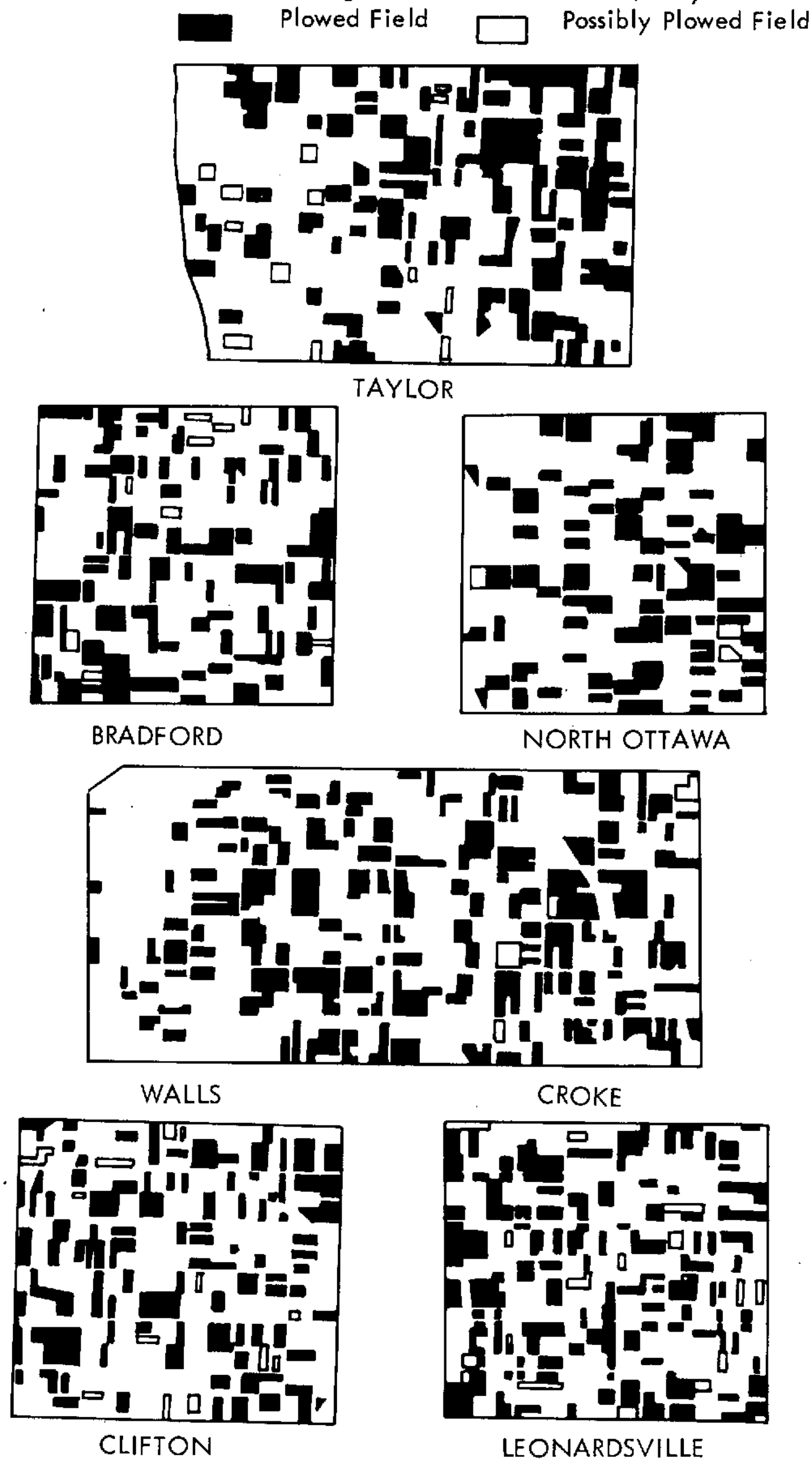


FIGURE 9 - Plowed fields - West Central Minnesota, July 5 and 6, 1973
from ERTS - 1 Images 1347-16432 & 1348-16491 Scale 1 : 205,000

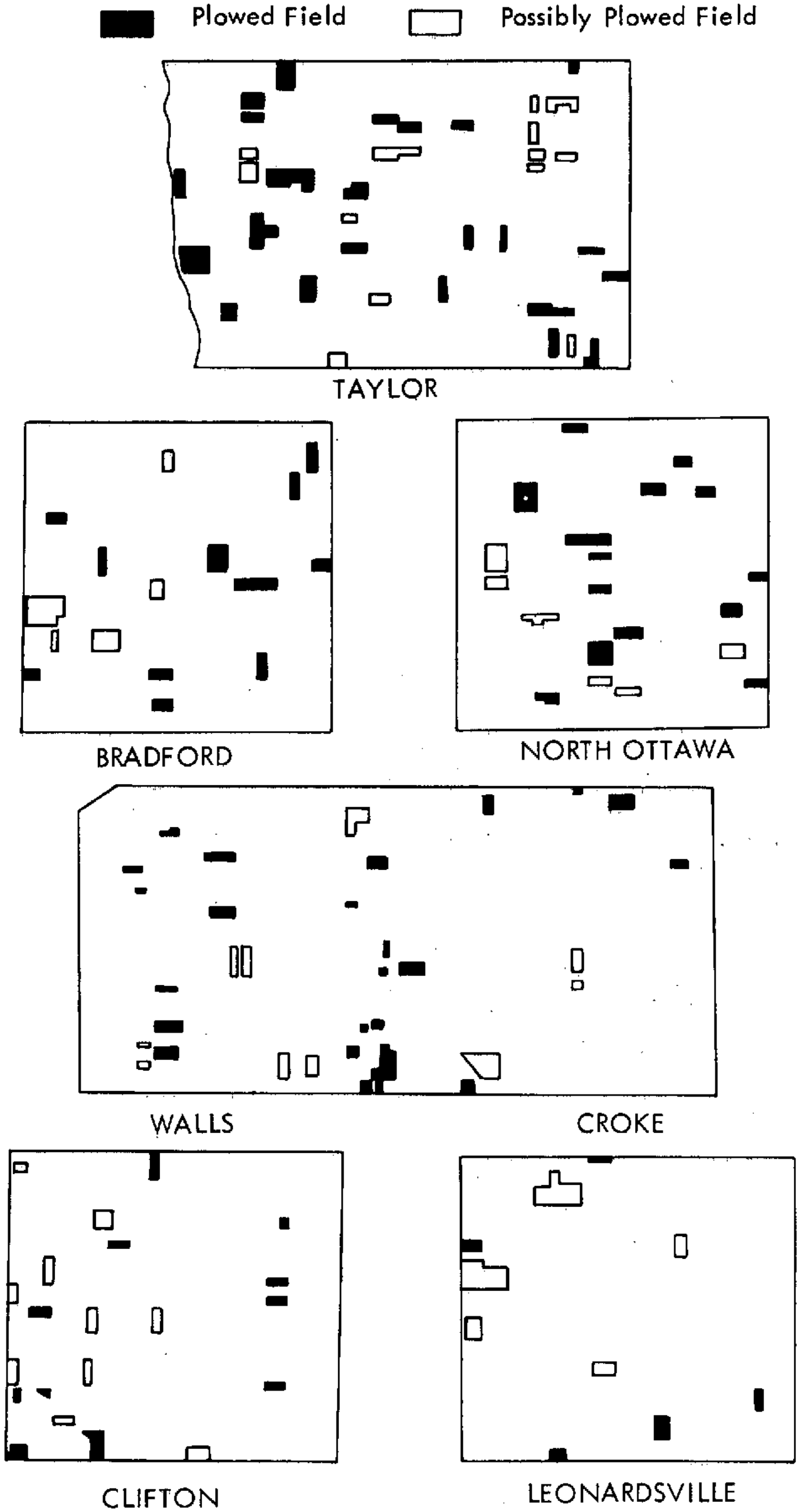


FIGURE 10 - Plowed fields - West Central Minnesota, August 10, 1973 from ERTS - 1 Image 1383-16430 Scale 1 : 205,000

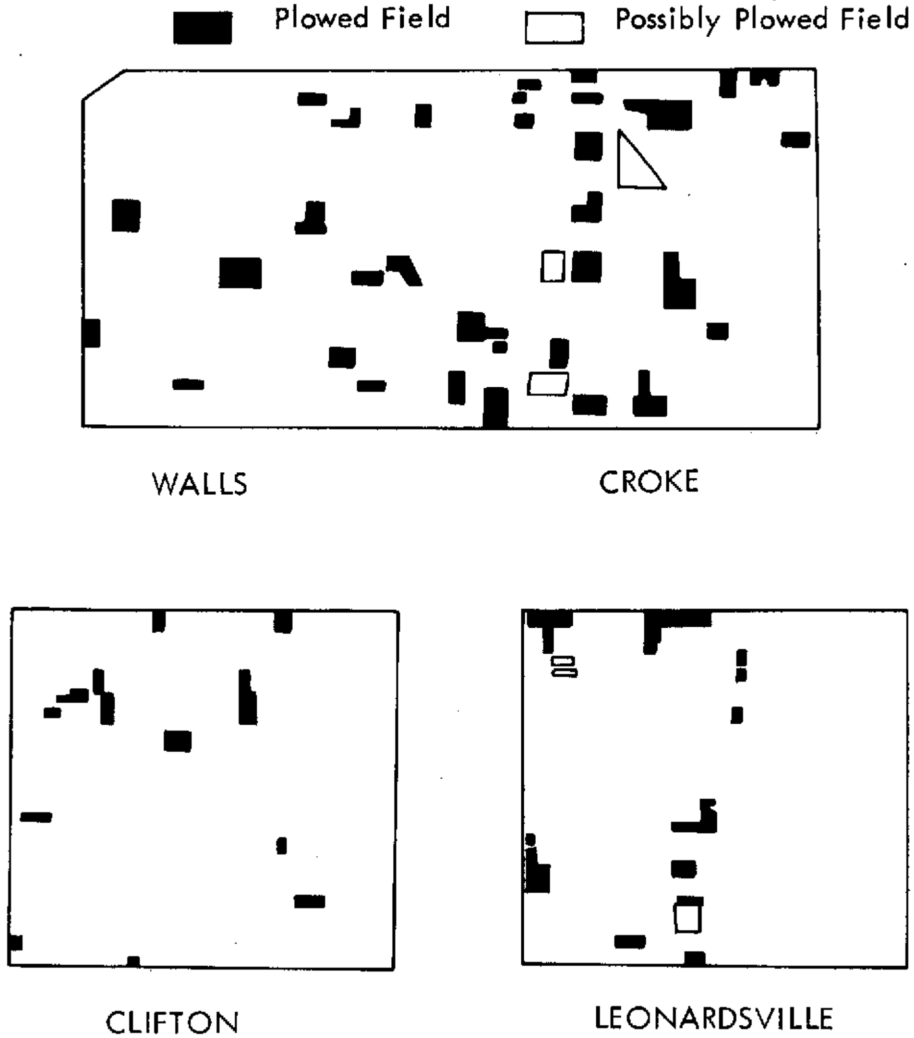


FIGURE 11 - Plowed fields - West Central Minnesota, August 28 and 29, 1973
from ERTS - 1 Images 1401-16424 & 1402-16482 Scale 1 : 205,000

Plowed Field   Possibly Plowed Field

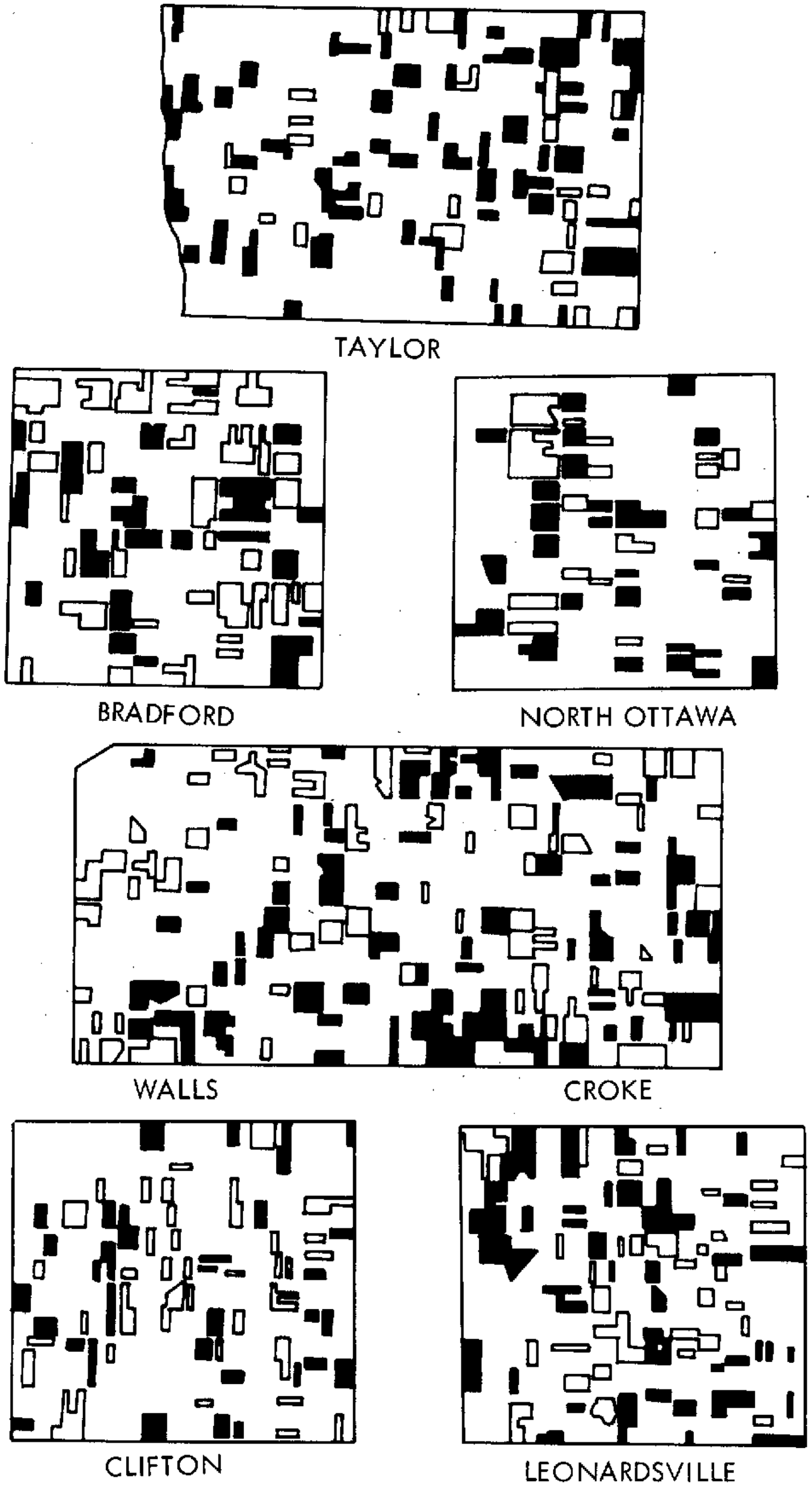
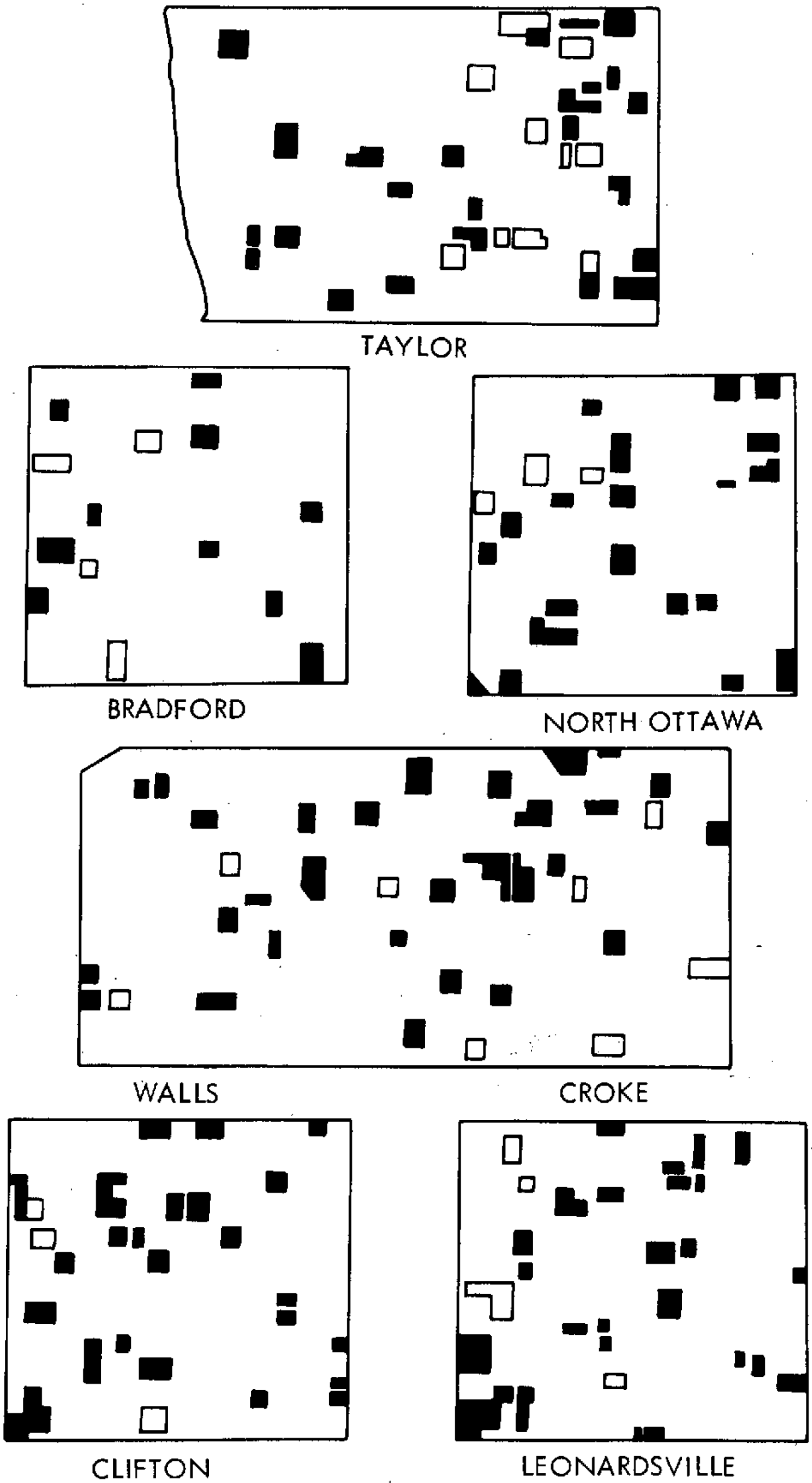


FIGURE 12 - Plowed fields - West Central Minnesota, October 4, 1973
from ERTS - 1 Image 1438-16473 Scale 1 : 205,000
Plowed Field Possibly Plowed Field



for this type of exercise in their planning operations, they lacked adequate field observations to properly assess the accuracy level.

To provide this type of assessment a second study area of four townships was chosen, where field data on cultivation was monitored under the MDNR "Operation Pheasant" program (Fig. 1). Several changes in the ERTS mapping program were made to increase accuracy in interpretation.

For the second study area (Fig. 1) township centered 35mm color slides were taken from back-lighted ERTS-1 system corrected (bulk) color transparencies. These slides were projected onto wall mounted 1:62,500 scale base maps with a zoom lens projector. The larger scale was chosen to make the products compatible with the ground and low level small frame aerial photography based maps produced by MDNR personnel. System corrected color images were used because it was determined that young emerging crops would be easily separated by the red-black contrast as opposed to the grey-black contrast on black and white frames. MDNR completed ground-truth mapping on August 6, 1972, April 7, 1973, and July 15, 1973. ERTS images were selected to maintain a 90-100% cloud-free date and to remain within one month of MDNR's date.

The evaluation showed marked seasonal variations in the quality of the results. Summer period (July 15, 1973) mapping was highly inaccurate. Comparison of the ERTS derived and ground truth maps highlighted the difficulties of summer mapping.

Obvious reasons leading to error can be summarized as follows:

(I) Color-contrast was minor.

(II) Bad satellite scan lines interrupting field patterns.

(III) Rapid decay of black tones due to drying. Dark tones are a function of surface moisture content. Dryer fields are difficult to distinguish from some unplowed areas.

(IV) Immature or late crops may be interpreted as plowed

fields (e.g., late beans and corn as well as drowned-out areas are often picked up as plowed or possibly plowed).

Interpretation of spring images does provide an accurate assessment of the acreage of cover free land carried over the winter (Table 1). The "Operation Pheasant" maps of the cover free land during winter are included along with the ERTS-1 derived maps of the second study area in Figure 13. These maps provide the basis for the cost comparison study that follows.

TABLE 1

Comparison of Plowed Land Carried Over Winter[1]

Township	Percent Plowed		Percent Possibly Plowed		Percent Other	
	Air Photo	ERTS	Air Photo	ERTS	Air Photo	ERTS
Galena-Waverly, Martin Co.	74.0	72.7	2.7	9.6	23.2	17.6
Jay-Lake Fremont, Martin Co.	66.3	60.7	9.4	14.3	24.7	24.8
Odin, Watonwon Co.	70.2	71.0	2.0	10.8	27.8	18.0
Nashville-Center Creek, Martin Co.	71.1	66.8	1.3	16.8	21.6	16.2

[1] The Air Photo analysis was part of MDNR project "Operation Pheasant" and included extensive ground observations. The dates for Air Photo coverage and ERTS coverage may vary as much as a month. Part of the discrepancy in the figures can be explained by very early spring plowing in this lag period.

Cost Comparisons

Three methods of mapping winter carry over of plowed fields provide the basis for comparison of costs for the four townships covered in Figure 13. Ground Mapping assumed that the field crew would be based in Madelia, Minnesota and that all field work would require full perdiem expenses (Table 2). The cost shown would be a maximum for a 4 township study because many areas would not

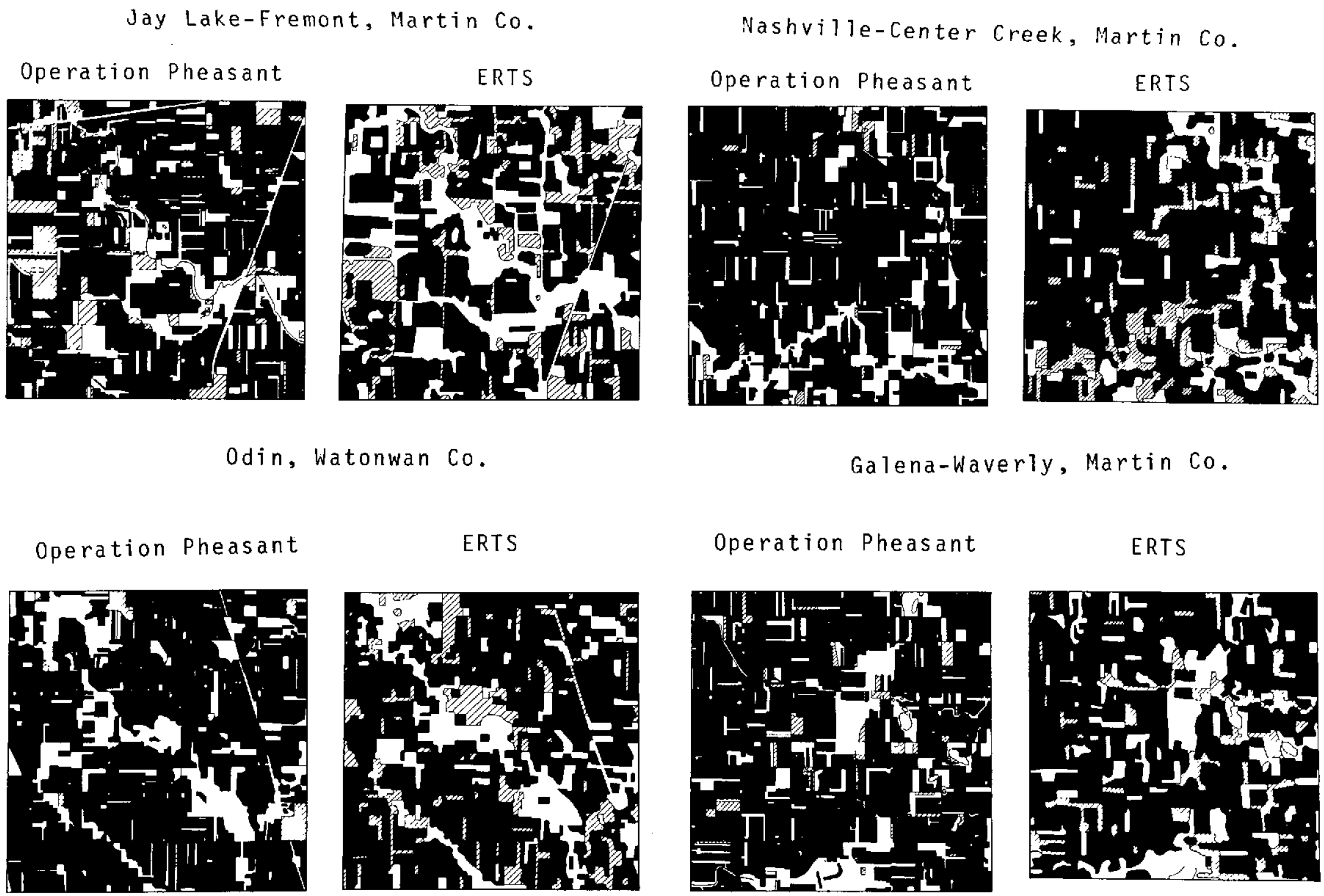


FIGURE 13 - Comparison of ERTS interpreted cover free land carried over winter with "Operation Pheasant" maps for test site 2, spring 1973. Black areas are plowed and diagonal lines represent possibly plowed. Scale = 1:190,000.

require stay overs by regional agency personnel during the mapping. Clearly the cost of ground mapping, which results in the lowest level of field boundary accuracy of the three methods, is too high for consideration in even moderate sized studies.

TABLE 2

Projected Cost Comparisons for Three Methods of Mapping Winter Carryover of Plowed Land for Four Townships (144 sq. miles) in South-Central Minnesota

	Ground Mapping	Light Aircraft Photography	ERTS-I imagery
Travel Manhours[1]	128 hrs. $896	12 hrs. $84	-------
Office Manhours[1]	16.8 hrs. $118	50 hrs. $350	7 hrs. $49
Automobile[2]	1788 mi. $250	80 mi. $11	-------
Aircraft & Pilot[3]	-------------	5 hrs. $135	-------
Fuel Consumption[4]	179 gal.	55 gal.	-------
Supply costs[5]	$10	$63	$10
Field Subsistence[6]	15 days $487	-----------	-------
Total costs	$1761	$643	$59
Cost per sq. mi.	$12.23	$4.46	$.41

[1] Man hours are charged at a $7/hour rate.

[2] Automobile travel is charged at 14¢/mi.

[3] Pilot and aircraft are charged at $27/hr.

[4] Fuel consumption is figured at 8 mpg. for field mapping, 14 mpg. for highway driving and 11 gal./hr. for aircraft.

[5] Supply costs include drafting materials, film, and camera depreciation.

[6] Field subsistence is figured at $32.50/day away from home base

Small frame air photos taken from MDNR light aircraft provide the present basis for data collection on habitat. The time figures are from the "Operation Pheasant" project that produced four of the maps in Figure 13. This method probably provides slightly more accurate results for total plowing than does ERTS imagery. It is most useful for providing accurate field boundary locations and also allows for detailed analysis of habitat conditions beyond simple analysis of plowing.

ERTS derived maps of plowing are substantially less expensive and are particularly efficient from an energy standpoint. The quality of results are highly comparable to small frame aerial photography except for the problem of field boundary locations.

Conclusions

ERTS-1 imagery has been demonstrated to have an accuracy level close to that of small frame aerial photography for studies of plowed land carried over winter. A variety of factors limit its accuracy at other seasons. Cost analysis shows that ERTS produced maps of plowing are by far the cheapest of the three methods examined and the system shows considerable promise for large area studies. The most critical limitation for the use of ERTS-1 imagery in studies of cover free land carried over winter is the uncertainty of cloud free coverage during the short useful time period.

References

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Acknowledgement

This work was partially supported by NASA contract NAS5-21801.

TWIN CITIES MINNESOTA METROPOLITAN AREA LAND USE

Dwight Brown, Joseph Gibson, Deborah Pile, Rob Warwick

INTRODUCTION

The Minnesota State Planning Agency (MSPA) and the University of Minnesota, Center for Urban and Regional Affairs (CURA) and the Department of Geography have cooperated to develop and evaluate methods for using ERTS-1 imagery to update and refine land based resource information in the Minnesota Land Management Information System (MLMIS). The Twin Cities Metropolitan Area land use project was selected as one of three initial full scale projects to test and demonstrate the utility of ERTS-1 imagery to Minnesota land resource problems (Sizer and Brown, 1974). The Metropolitan Area along with portions of Itasca County provided the basis for evaluation of ERTS-1 applications to a general land use information in Minnesota.

The most recent detailed land use map for the Twin Cities area was produced by the Metropolitan Council in 1968, using 1966 low altitude aerial photography. Only the urbanized portions of the 7 county area were covered by the 1:125,000 scale color map. Initial efforts to apply ERTS-1 images to urban land use mapping examined the possibility of using the Metropolitan Council classification and mapping scale. The operational definitions for land use classes employed in the Metropolitan Council map were found to be inoperable with ERTS-1 imagery.

A classification was developed to maximize the detail of accurate information extracted from ERTS images while preserving a degree of correspondence with the Metropolitan Council classification.

INTERPRETATION AND MAPPING PROCEDURES

Ektachrome slides, copied from back lighted 9" ERTS-1 MSS system corrected color transparencies, were interpreted by projection onto a wall mounted 1:125,000 scale base map of the seven county area. Overlapping slides were produced by a 35mm, single lens reflex camera fitted with extension tubes, a 50mm lens, and a behind-the-lens light meter and mounted on a variable intensity light table. Each slide covered only a small portion of the study area, generally about 200 sq. mi. Variances in the season of maximum detectability for some classes of land use necessitated the use of several imagery dates. Interpretation and mapping were accomplished by 2 person work teams, which significantly reduced setup time.

The initial draft of the land use map was edited prior to production of cartographic plates for each class. It was determined that the detail of the map, which used 40 acre sized mapping units (a land use had to be extensive enough to dominate a floating 40 acre cell), did not warrant final cartographic scale larger than 1:190,000. Thus, the plates for each class were prepared at this reduced scale.

The separation of the C.B.D. from the Commercial-Industrial-Institutional class is based on the high density of tall structures with considerable shadow area, and a total lack of vegetation. This desert-like landscape contrasts sharply with the urban forest canopy of the older residential areas and the newer suburban savanna-like landscape. The use of these subjective vegetation-urban land use relations coupled with the difficulty of mapping units below 40 acres

in size are the severest limitations for the employment of these data for detailed urban land use planning. The final copy is included in the map pocket.

EVALUATION

Two types of errors can be incorporated into a map derived from remote sensing imagery. The first is incorrect class assignment of a mapped unit. The second is incorrect map location of the class boundary separating two mapped units. The latter error is the more difficult to evaluate because the complexity of class boundaries is largely a function of the density of locational information. In this respect the high altitude aerial photography, ground interpretation, and topographic maps used as the basis for evaluation and the ERTS-1 imagery are not compatible. Evaluation of boundary location error is extremely costly, and is highly dependent on the quality of a series of highly subjective human judgments. For these reasons quantitative evaluation of error will be restricted to errors of class assignment. Existence of boundary location error is acknowledged and the contributing factors are described below.

The disagreement between ERTS-1-interpreted class boundary location and class boundary location interpreted from other information sources will be defined as boundary location error. However, it must be recognized that the fallibility of other data sources makes the specific assignment of error suspect. To evaluate interpretation error, the ERTS information and comparative information must be converted to a common base, in this instance a single base map produced by the Metropolitan Council at a scale of 1:125,000. None of the information used in this

study originates in this format; but, it was transformed to facilitate evaluation.

Boundary error not attributable to the ERTS image interpretation can result from:

1) locational error in the transformation of base data to the map.
2) locational error in the transformation of ERTS-1 data to the map.
3) locational error in the interpretation of base data.
4) change in the boundary location in the time period between base data collection and ERTS-1 coverage.

All four error types undoubtedly exist to some degree.

Boundary errors attributable to ERTS image characteristics result from the inability with the coarse pixel (1.1 acre) information and occasionally from insufficient image contrast to define intricate boundaries.

Class assignment error results primarily from insufficient contrast between two land use classes. Table 1 shows a summary of class assignment errors for 528 random points. The ERTS-1 interpreted classes shown on the map were compared with NASA and commercial high altitude aerial photography, recent topographic maps, and ground observations. The definition of Central Business District is primarily locational and not separated from Commercial-Industrial-Institutional for purposes of evaluation. Likewise, because the two residential classes are separated by subjective vegetation and associated density interpretations, they are grouped for evaluation. Residential 1 is distinctive primarily because the urban

TABLE 1

ACCURACY OF ERTS INTERPRETATION

ERTS Classes	Basic Information *												
	1 & 2		3 & 4		5		6		7		8		
	N	%	N	%	N	%	N	%	N	%	N	%	N
1. & 2. C.B.D. & CII	31	100	0	0	0	0	0	0	0	0	0	0	31
3. & 4. Residential 1&2	3	4	56	79	0	0	1	1	0	0	11	15	71
5. Water	0	0	0	0	30	94	0	0	1	3	1	3	32
6. Extractive	0	0	0	0	0	0	1	100	0	0	0	0	1
7. Forest	0	0	1	1	1	1	0	0	86	93	4	4	92
8. Other	3	1	4	1	3	1	0	0	4	1	287	95	301
cells	37		61		34		2		91		303		528

* Base information is derived from a combination of 1972 NASA and 1968 commercial high altitude aerial photography, 1972 revised topographic maps and ground investigation of the land use that dominates a 40 acre area around the 528 randomly selected points.

forest gives it a significantly different tonal response than the newer suburban savanna landscape, which has a greater expanse of grass with scattered smaller trees. The threshold for detection of developed residential areas ranges from 10 to 20 houses per 40 acre mapping unit.

Two other Metropolitan Area land use studies that used ERTS-1 data provide some basis for evaluating the results of this study. The accuracy of class assignment is favorable when compared with similar studies by Honeywell of a portion of Ramsey Co. (Kirvida et al., 1974) and the Dartmouth College study of southern New England (Simpson et al., 1974). Table 2 shows the relative accuracies attained in each of these studies. Classes are grouped where necessary to maximize

TABLE 2

ACCURACY OF LAND USE INTERPRETATIONS FOR THREE STUDIES

	Twin Cities Metro. Area 40 Acre Mapping Unit N = 528	Ramsey Co., Mn. Honeywell 1 Acre Unit N = 1,792	Southern New England Dartmouth Study 62 acre units N = 2,331	
			unenhanced imagery	enhanced imagery
	%	%	%	%
Commercial[a]	100	93	63	65
Residential[b]	79	88	64	71
Water	94	100	66	64
Extractive	100	c	c	c
Forest	94	c	35	36
Other	90	77	44	49
Average	93	96	58	63

a. Includes all commercial and transportation classes.
b. Includes all residential classes.
c. These figures were included in other.

compatibility. Strict comparison is not possible because of the number of classes, variety of operational definitions, mapping unit sizes, and environmental settings. The Honeywell study was based on digital data while the Dartmouth study employed manual interpretation of both conventional and enhanced ERTS-1 images.

These same studies also provide a basis for cost comparison. Preliminary manual ERTS-1 image interpretation for portions of the Twin Cities Metropolitan Area and Itasca Co. yielded additional interpretation cost figures that correspond closely with the figures for the entire 7 county area (Table 3). When compared with other studies the costs

TABLE 3

COST COMPARISONS

	Area Mapped (mi.^{2})	No. Classes	Mapping Unit Size (Acres)	Interp. Time (man hrs.)	Interp. Rate (Sq.mi./hr.)	Int.Cost Labor only @$7/hr. ($/sq.mi.)
T.C. Metro Area (Prelim.map)	1,728	9	100	39	44	$.158
Itasca Co. (Prelim. map)	1,100	14	25	20.5	53.7	.130
Twin Cities 7 County Area	2,968	8	40	75	39.6	.177
New England (Dartmouth College)	15,000	9	62	675	22.2	.315[1]
Ramsey Co., Mn. (Honeywell) Digital Computer Analysis	140	4	1	-	-	1.80*

* cost includes 5 class map production

[1] This figure is based on their reported labor requirements. Their total reported costs are $1.06 from unenhanced images and $1.38 from enhanced images.

achieved in this study are significantly lower. However, strict comparisons of costs have the same limitations as comparisons of accuracy. Even with uniform class definitions and methodologies a single interpreter would produce different accuracy and cost results in different geographic areas. The problem of transferring results is difficult to overemphasize. Similarly, results obtained from different seasons or same seasons in different years will differ.

SUMMARY AND CONCLUSIONS

ERTS-1 imagery can be used for low cost identification of urban land use in the Metropolitan Minneapolis-St. Paul Area with a fairly high level of accuracy. Two basic limitations of manual interpretation are the size of mapping units and the need to use class definitions. Only limited success was attained in efforts to visually discriminate land use units below 40 acres when mapping at a 1:125,000 scale. The separation of the two residential classes employed in this study was based on vegetation differences. In the Twin Cities area the crown cover density of the urban forest has some relationship with the age and density of residential areas. However, such inference lacks precision and transferability to other areas. The results of this study are probably most useful at the state level of land use inventory and planning, where detailed lot and block information are not necessary. The cost of using ERTS-1 imagery for state level land use information is sufficiently lower than other data sources, and the accuracy level is sufficiently high to dictate strong consideration of its use where the mapping unit and class detail employed in this study adequately satisfy data needs.

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ACKNOWLEDGEMENTS

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MONITORING SURFACE WATER DYNAMICS IN MINNESOTA

Dwight A. Brown, Richard Skaggs, John M. Smiley, Eliahu Stern

INTRODUCTION

> Overson Lake is listed on page 296 of 'An Inventory of Minnesota Lakes,' a state publication.
> Overson Lake no longer has any water in it, however... The water in Overson Lake disappeared early last month when an unidentified person or persons used dynamite to blow open a short connecting link from the lake to a newly dug 15-foot drainage ditch...A few days before the blast conservation officers had warned...that the lake could not be drained without permit. Was that public water that went down the ditch? Or did the blast release privately owned water creating more cropland for the farm? (Shara, 1974)

Thus begins a recent feature article in the Minneapolis Tribune which illustrates a number of problems related to planning and management of Minnesota's surface water resources.

The first problem concerns the identification and locational documentation of public waters. The second relates to maintenance of an accurate up-to-date inventory. A third problem relates to the monitoring by enforcement personnel of illegal drainage.

The Minnesota Department of Natural Resources (MDNR) is charged with the responsibility of defining and identifying public water in the state. At present the "Minnesota Lakes Inventory" (Bulletin 25) is employed for surface water planning and management. However, Bulletin 25 is now of limited value because of the age of data, the use of basin area without indication of water extent, and the omission of basins under 10 acres. Additional limitations are inherited from the use of existing aerial photography in compiling the inventory. In some counties, only aerial photography taken during 1930's and 1950's dry periods was available, thus allowing some shallow seasonal lakes to escape detection.

Discussions with administrative heads of each division in MDNR and various personnel from The Minnesota State Planning

Agency (MSPA), the Center for Urban and Regional Affairs, University of Minnesota (CURA) and a variety of other state and university centers led to the establishment of a pilot project to examine the cost and utility of ERTS-1 imagery for quickly updating surface water information. A cooperative project was established, based on the results of two studies done in the Geography Department at the University of Minnesota and supported by a NASA grant to the University of Minnesota Space Science Center (Prestin,1974 and Brown and Skaggs,1974). Four areas of the state were indicated by MDNR, the dominant user agency, as tests for the pilot project. Highest priority was given to the copper-nickel study area in Northeastern Minnesota and to the Twin Cities Metropolitan area. Second priority was given to sites in prairie agricultural areas of southwestern Minnesota and the forest-prairie transition zone in west central Minnesota.

The Twin Cities area had been completed by the Department of Geography project but it was deemed useful to produce a complete wall map of the area at a scale compatible with the Twin Cities Metropolitan Council's map series.

The stated needs of field personnel, dealing with permits and enforcement, indicated that the product of the pilot project should be updated 1:24,000 and 1:62,500 scale topographic map overlays that showed the extent of seasonal variations in open surface water verifiable with ERTS-1 imagery. These transparent acetate overlays could then be used by field personnel and could also serve as a locationally accurate data base to be digitized and entered in a water information system. The maps could also provide the basis for producing highly accurate maps at scales as small as 1:125,000. The Twin Cities Metropolitan area was mapped at this scale using a mosaic of 45 topographic maps so that a comparison could be made between the costs of mapping at very large scale and reducing the maps as opposed to remapping at this scale directly from the imagery.

This report will describe the procedures used to produce the

two map products described above, detail and compare costs of various products, and compare the map data to that included in existing and traditional sources of information on surface water. Comparisons will be made in lieu of measurements of accuracy because it has become clear to the researchers that these maps, based on multi-season ERTS-1 coverage coupled with good topographic maps, yield a product that far exceeds the quality of any type of "ground truth" now available or potentially available short of an ERTS underflight photographic mission that would rival the corn blight project. Furthermore, the cost of producing this product is very low relative to the cost of producing any of the existing information.

MAPPING PROCEDURES

Three data sources provide the basis for producing the 1:24,000 and 1:62,500 transparent topographic map overlays. They are good quality topographic maps and good quality ERTS-1 MSS system corrected (bulk) color transparencies for two dates. The two dates were selected to maximize the range of observed water area. The maximum and minimum water images were used to produce 35mm ektachrome quad-centered slides from back lighted ERTS-1 transparencies. The single lens reflex camera used was fitted with extension tubes and a through-the-lens-light meter. Total area covered by the slides was 3 to 4 times the quadrangle area in order to minimize optical distortion. The topographic maps were mounted on the wall and the slides were projected with a remote focus, zoom lens slide projector. The use of two people in the operations greatly speeded up the slide registration and mapping procedures.

The maximum geometric discrepancies between the map and projected image were about .1 inch over a 1:24,000 scale map. With the use of base maps other than USGS topographic quadrangles the geometric discrepancies were much larger.

Once the slide image was registered a stable base drafting

acetate, with previously drawn USGS water boundaries, was registered over the topographic map. The topographic map was then removed to expose the white wall mounting board, thus maximizing color contrasts. The wall mount mapping procedure was found to be less time consuming in registration and produced a higher contrast image for interpretation than did rear projection drafting tables. The latter are probably less fatiguing for interpreters on long tedious interpretation jobs; but, for this operation image registration time was a significant portion of the total time.

The initial image interpreted and mapped was the maximum aerial extent of open water followed by registration and mapping of the minimum extent of open water image. Once the interpretation procedure was complete, the acetate was taken to a drafting table and registered on the topographic quadrangle. The extent and limits of water were then interpreted and corrected on the topographic map, using the ERTS verified location of water. With this procedure it is possible to exercise judgement and interpret the extent of water in narrows that are not detectable on ERTS, if the level of water can be verified in the two connected wider basins.

Although confusion of plowed fields and cloud shadows with lakes was not a problem with the images used in this study, confusion is known to occur. By using the above method the chance for such error is very small because lakes are restricted to very specific topographic locations. These locations on the map have well defined geometries that would have a very low order of probability of corresponding with plowed fields and cloud shadows.

The next step was final drafting and lettering of the maps so that transparent overlays could be produced for field personnel. Final drafting was done by hand; but, may be done by continuous line plotters if the pencil sheets are digitized for entry into a water information system.

The legends were mass produced on photographic transparencies

to enable the production of contact autopositive topographic map overlays.

Figure 1 shows the location of areas where water mapping has been carried out to produce the variety of maps necessary for a reasonable cost analysis. The four areas indicated include new and old topographic maps, both the 1:62,500 and 1:24,000 series, and 5 distinctly different environmental settings. Figure 2 shows the index for each of the quadrangles and reduced versions of the quadrangles are shown in Figures 3-36.

REGIONAL MAPPING

The second phase in this project was to examine the possibility of using the quadrangle maps as a basis for producing larger area maps. Highest priority for this task was given to the Twin Cities Metropolitan area. These quadrangles had already been produced under the project that provided the interpretation procedures used in this pilot project (Brown and Skaggs, 1974).

Early in the research program examining ERTS-1 applications to Minnesota land use ERTS images were used to produce 1:125,000 maps of surface water. For this study a variety of west-central Minnesota counties were mapped with 70mm system corrected band 7 MSS images projected on a county highway map base. Pencil copies of these maps required from 20 minutes to four hours per county depending on size and complexity of the county. Transferring these findings to the Twin Cities area yields a final inked copy at a 1:125,000 scale at 30 man hours. Such a map, while low cost, has several distinct limitations. Few lakes under 20 acres were detected with this mapping procedure. Secondly, the geometry of the county highway maps was not adequate for rapid image registration and mosaicing of multiple county areas. Imprecise lake locations were a result.

There is more detail on the 1:24,000 quads than can be portrayed on the 1:125,000 scale maps. However, it is possible to show more information than was produced in the procedure

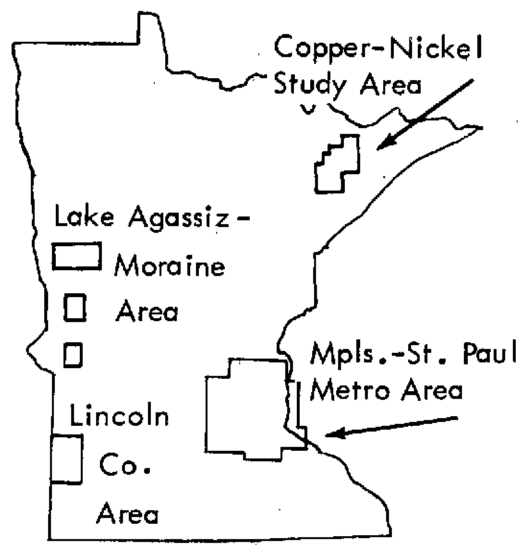
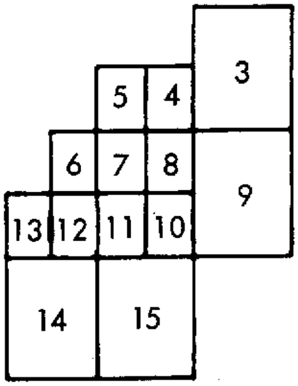
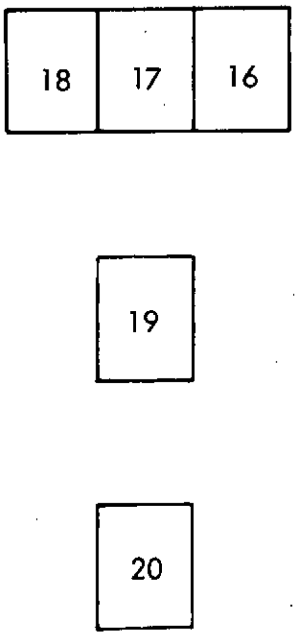


Figure 1. Location of Surface Water Study Areas.



Copper-Nickel Study Area

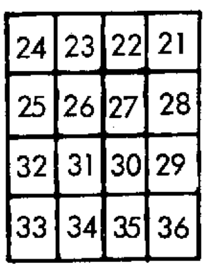
3. Gabbro Lake
4. Kangas Bay
5. Bear Island Lake
6. Isaac Lake
7. Babbitt
8. Babbitt NE
9. Greenwood Lake
10. Babbitt SE
11. Babbitt SW
12. Allen
13. Aurora
14. Markham
15. Brimson



Lake Agassiz-Moraine Area

16. Vergas
17. Pelican Rapids
18. Barnesville
19. Wendell
20. Chokio

Lincoln County Area



21. Taunton
22. Porter
23. Canby
24. Hendricks
25. Lake Benton NW
26. Lake Benton NE
27. Arco
28. Gislason Lake
29. Dead Coon Lake
30. Tyler
31. Lake Benton
32. Lake Benton SW
33. Elkton
34. Verdi
35. Ruthton NW
36. Ruthton

Figure 2. Location of Figures 3-36.

GABBRO LAKE QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

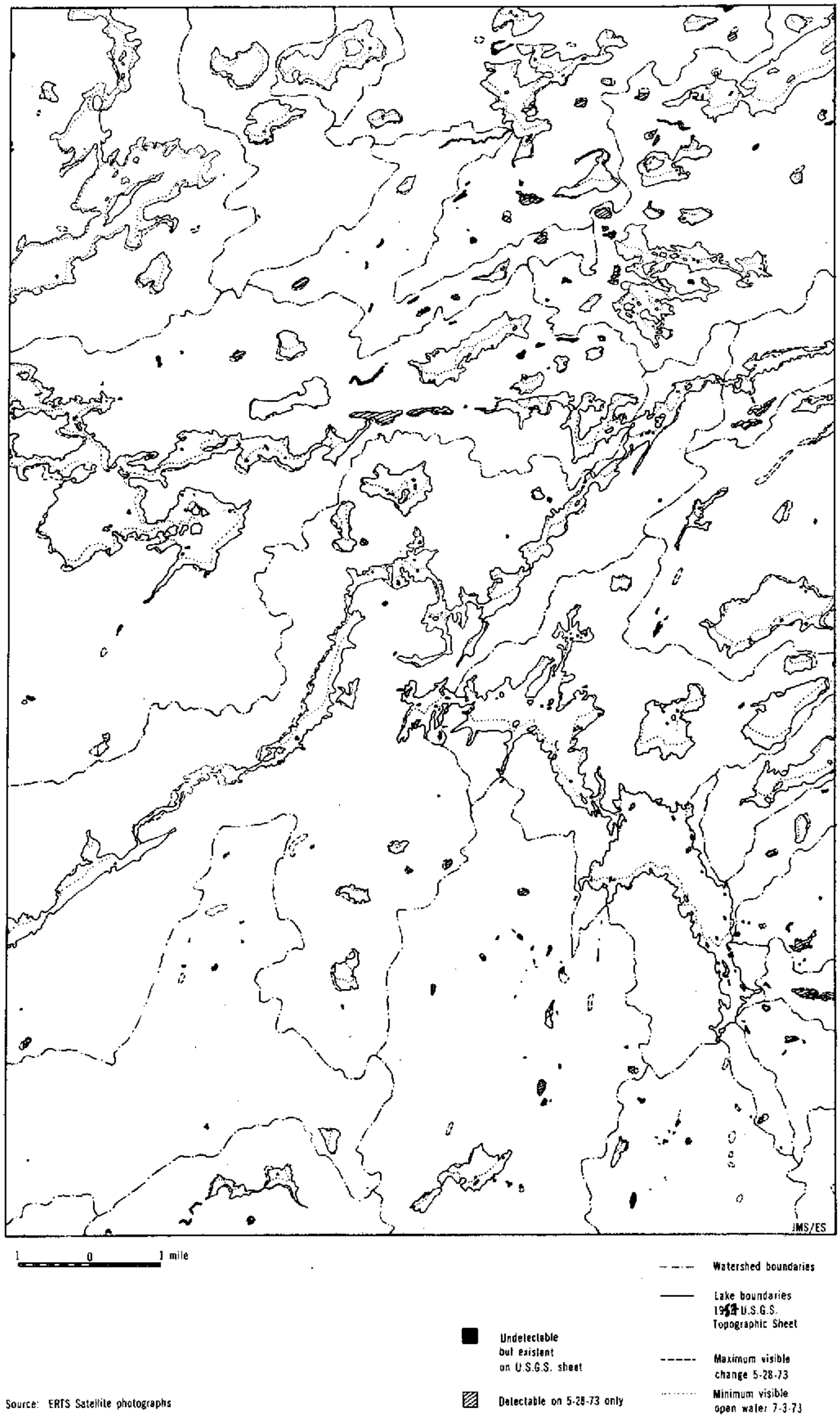
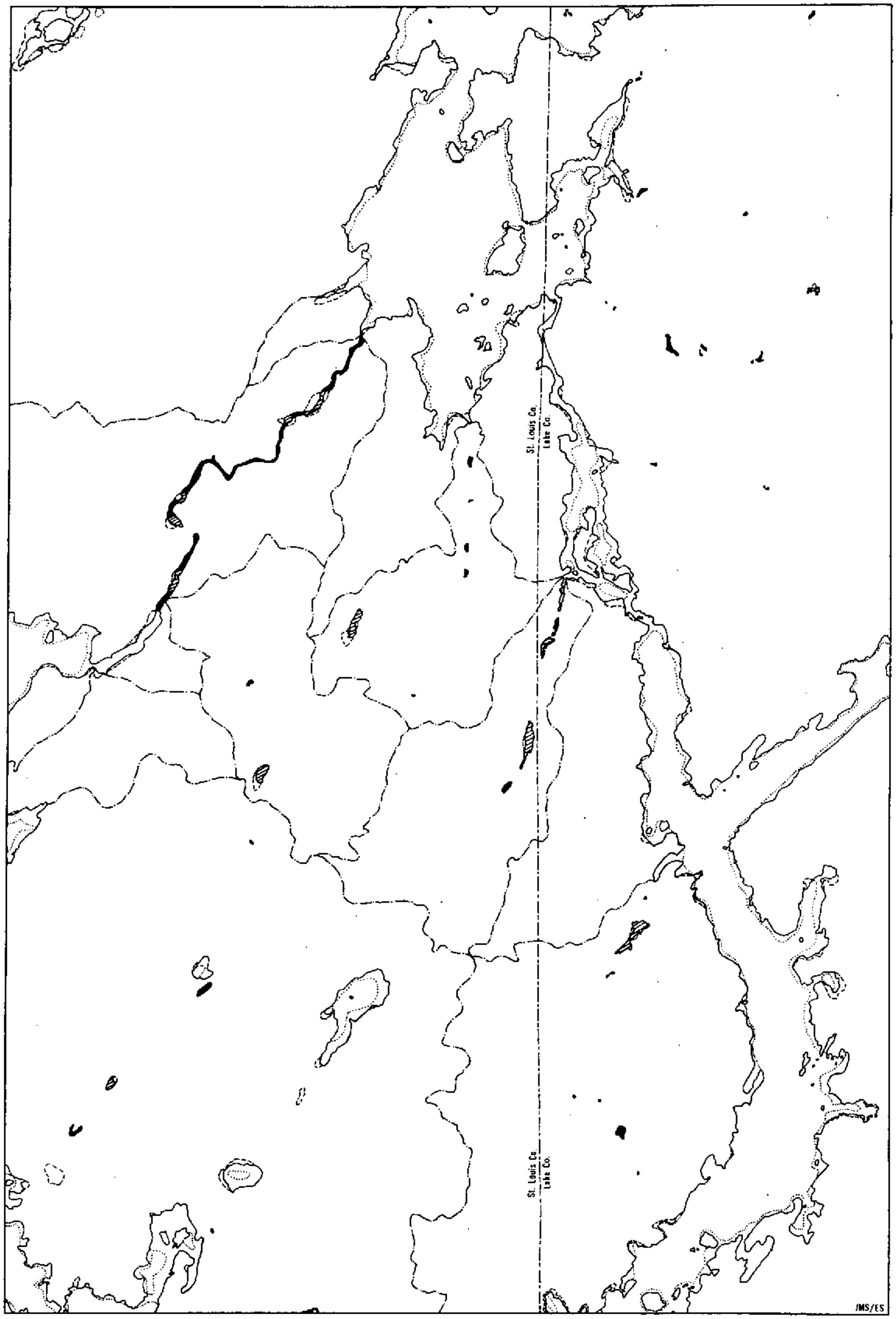


Figure 3.

KANGAS BAY QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



0 1 mile

County boundary

Watershed boundaries

Lake boundaries
1965 U.S.G.S. Topographic Sheet

Maximum visible change 5-28-73

Minimum visible open water 7-21-73

Undetectable but existent on U.S.G.S. sheet

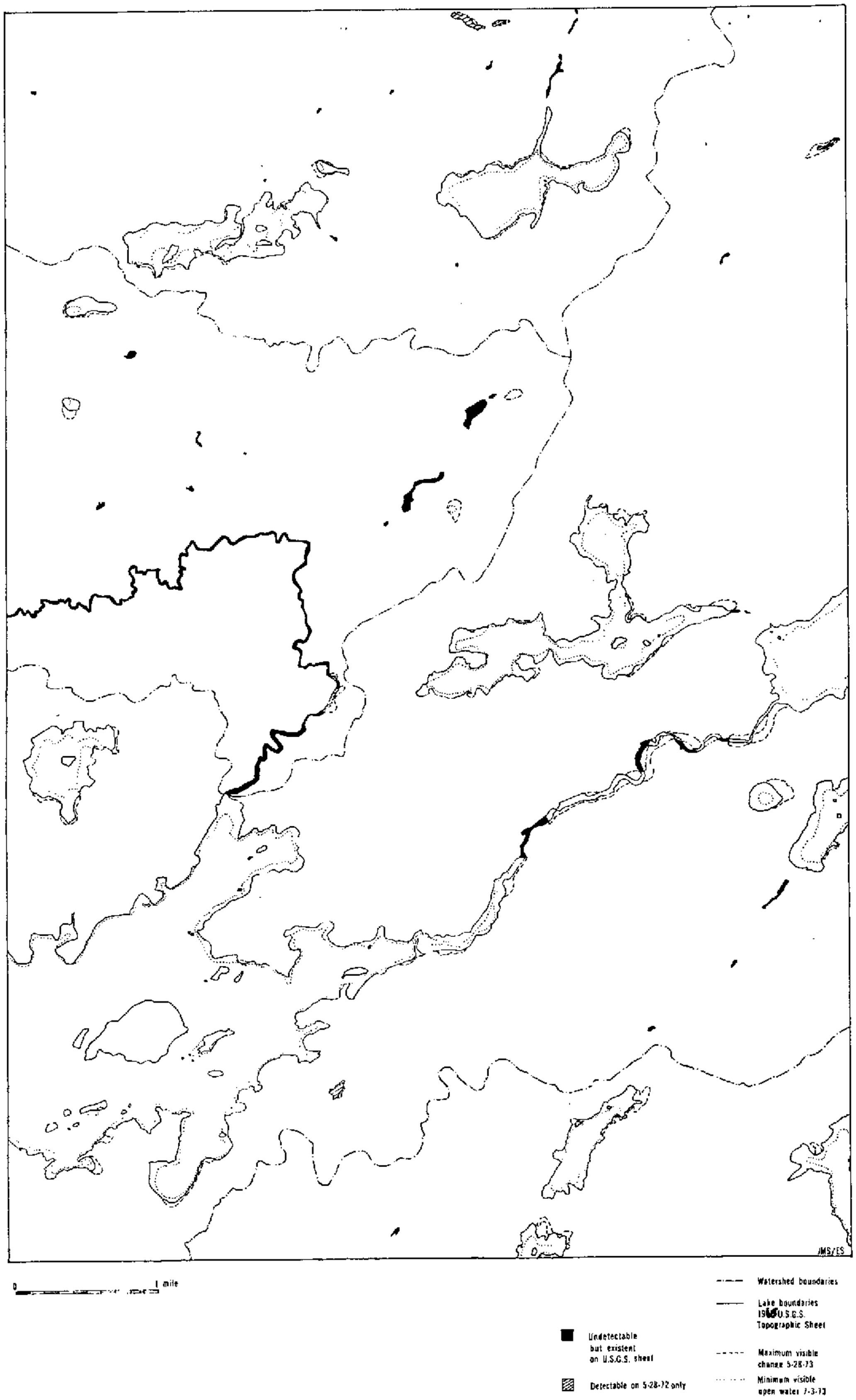
Detectable on 5-28-73 only

Source: ERTS Satellite photographs

Figure 4.

BEAR ISLAND QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



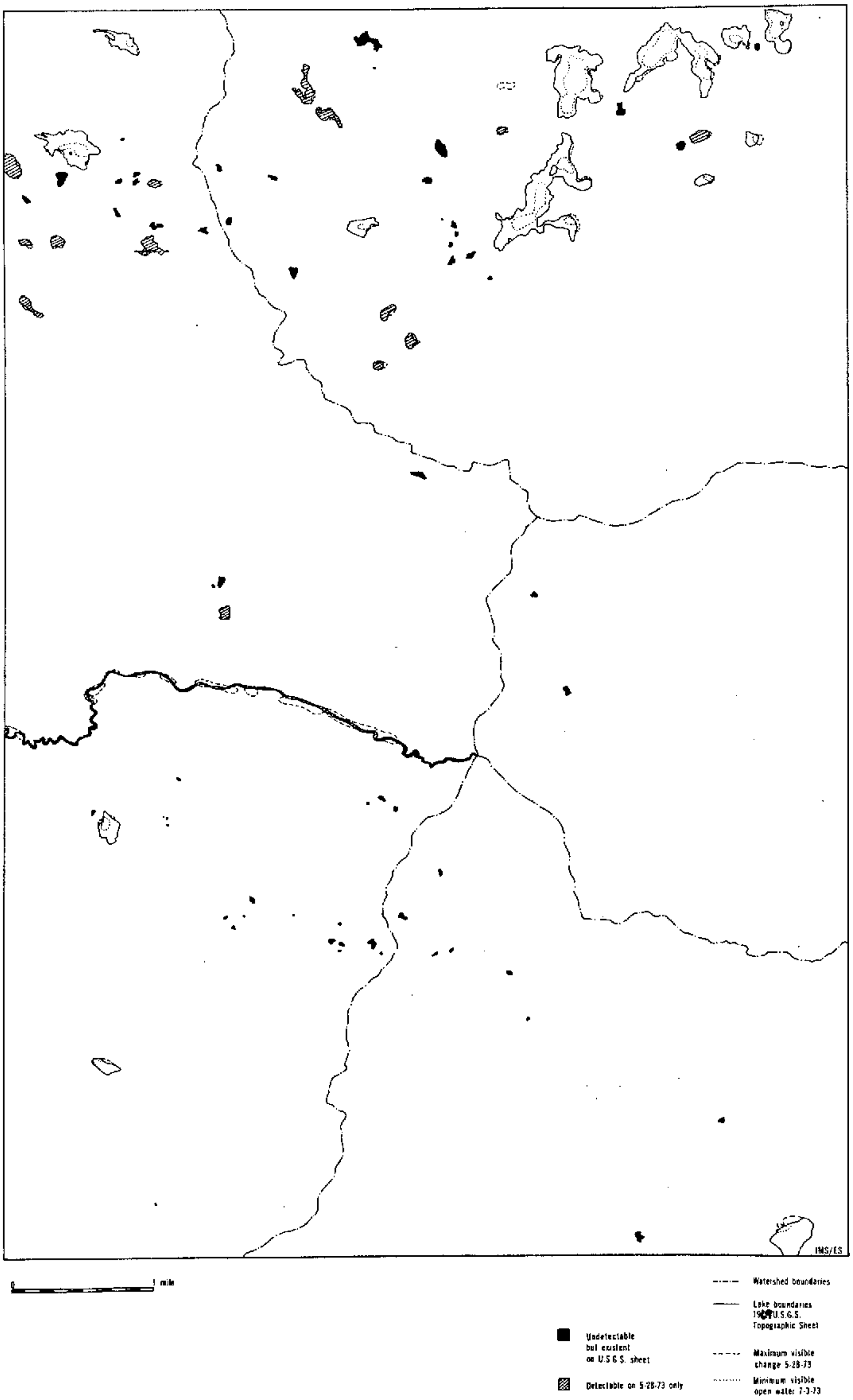
Source: ERTS Satellite photographs

Figure 5.

ORIGINAL PAGE IS
OF POOR QUALITY

ISAAC LAKE QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



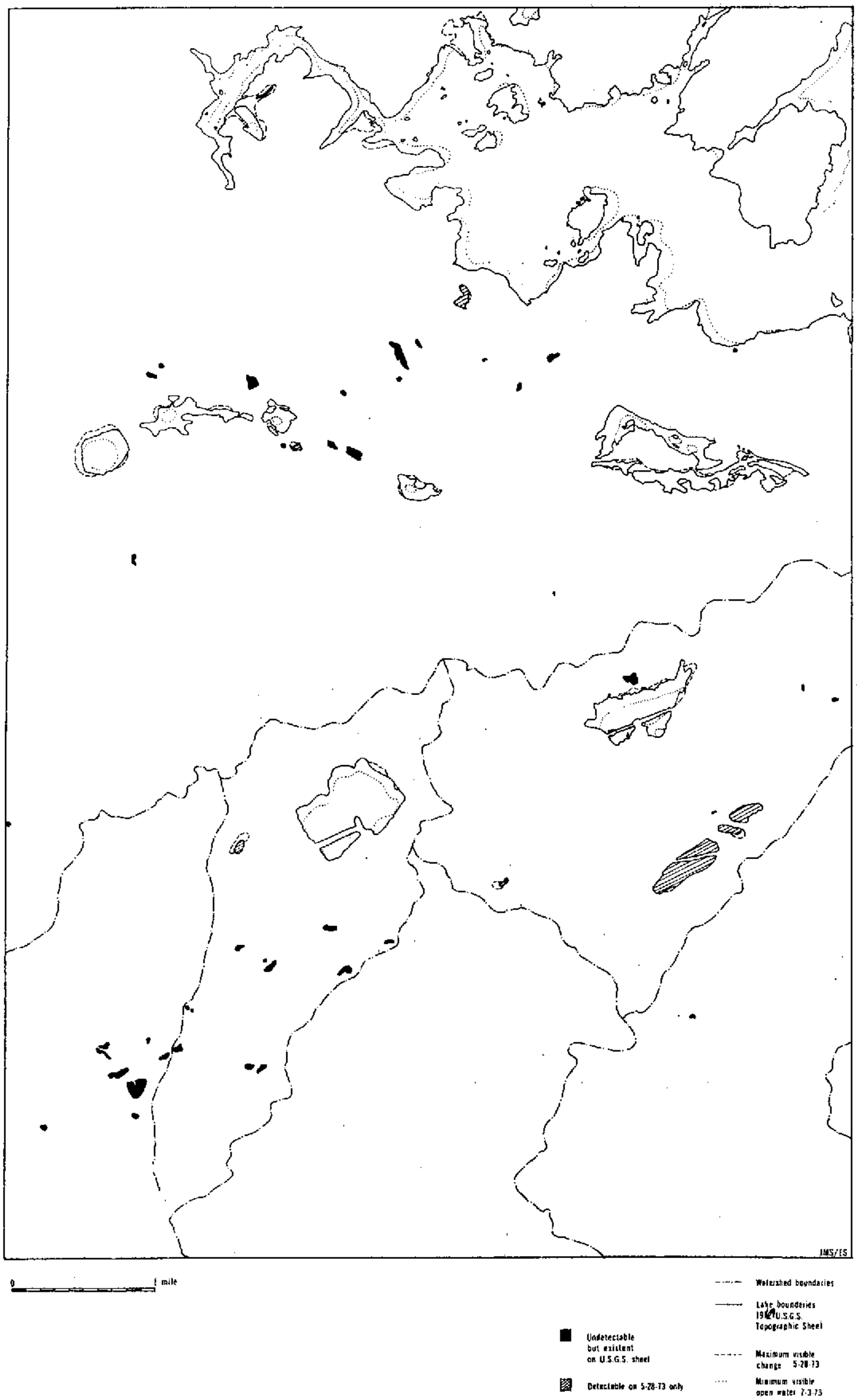
Source: ERTS Satellite photographs

Figure 6.

11

BABBITT QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

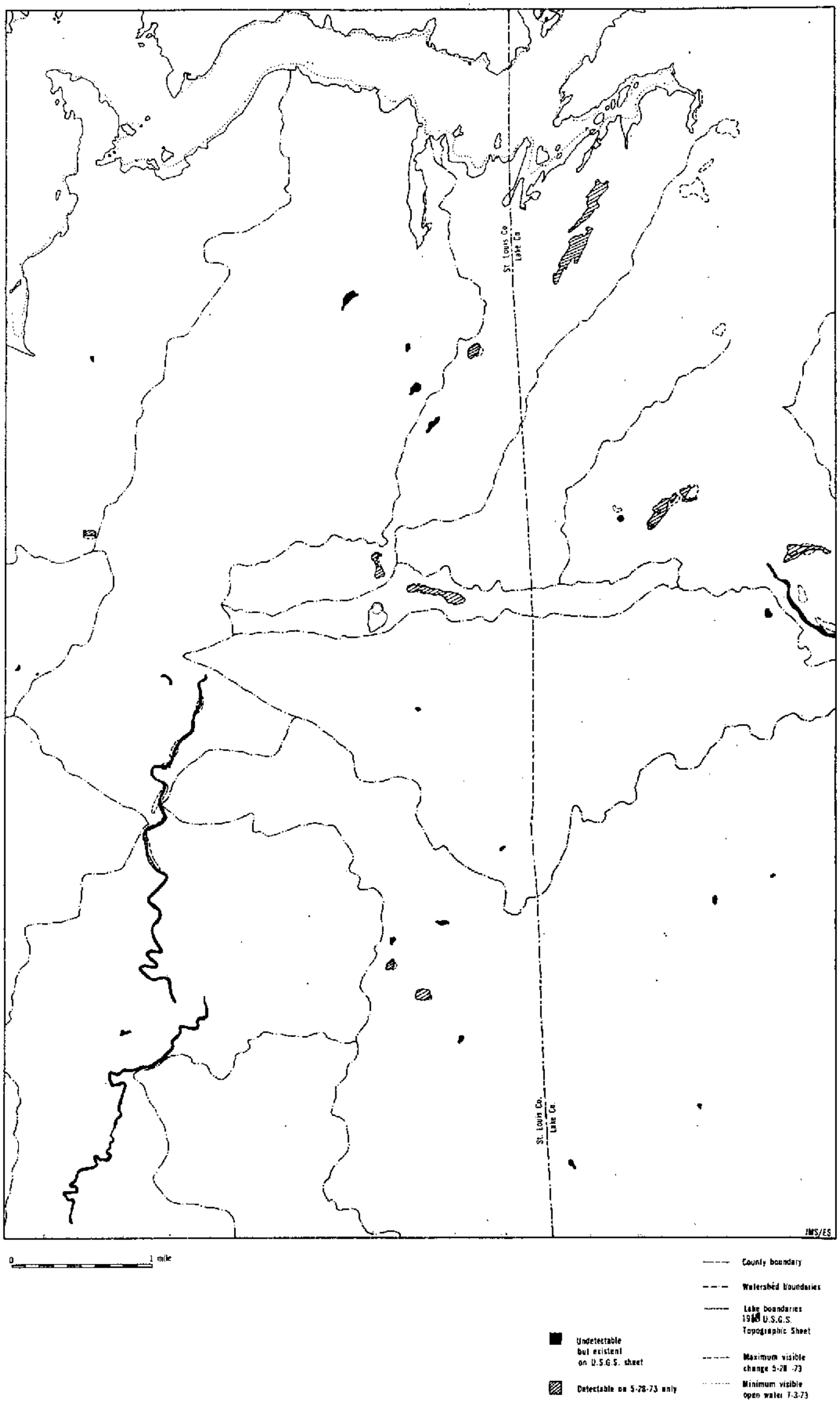


Source: ERTS Satellite photographs

Figure 7.

BABBITT NE QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

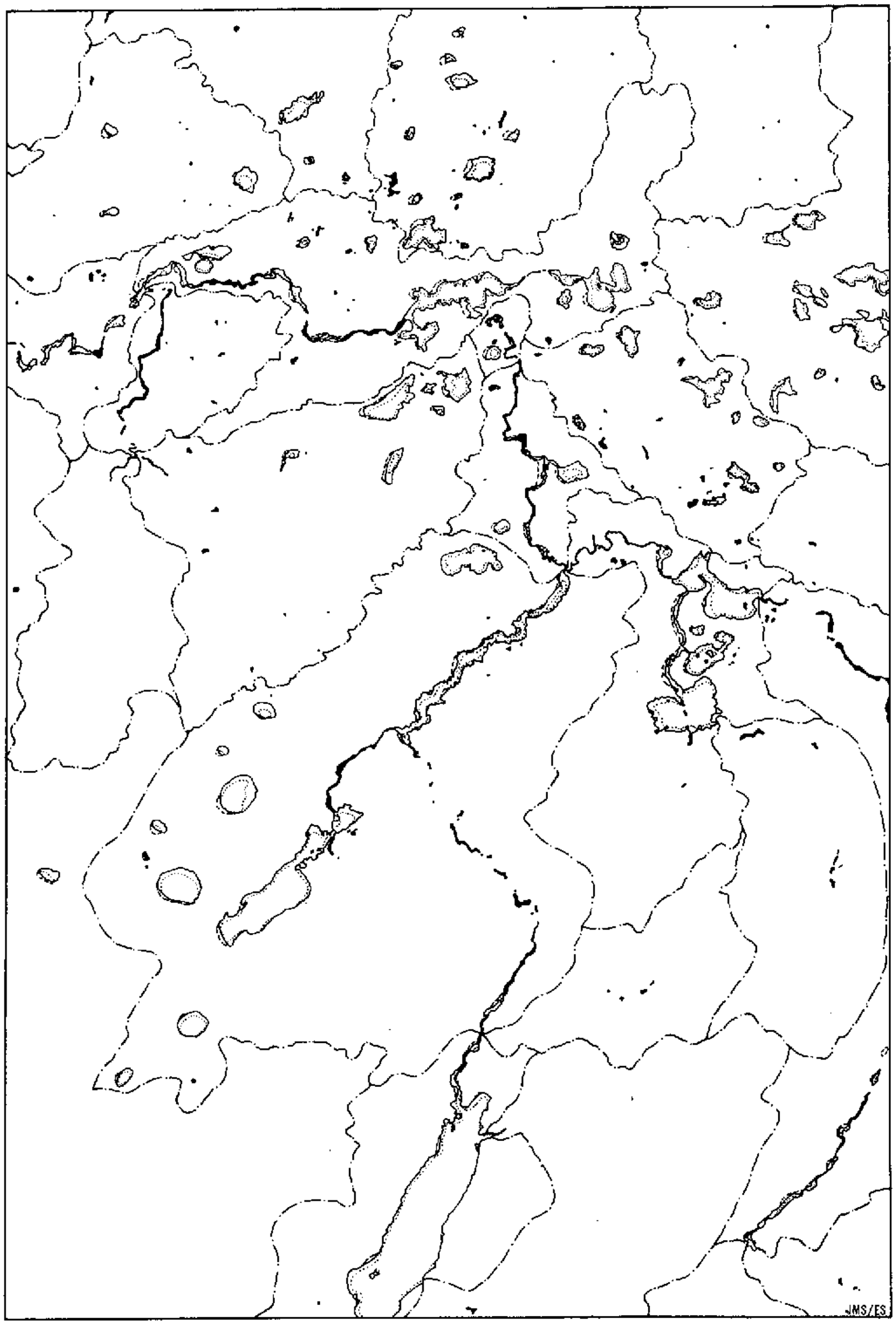


Source: ERTS Satellite photographs

Figure 8.

GREENWOOD LAKE QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



0 1 mile

Watershed boundaries

Lake boundaries 19[illegible] U.S.G.S. Topographic Sheet

Undetectable but existent on U.S.G.S. sheet

Maximum visible change 9-18-72

Source: ERTS Satellite photographs

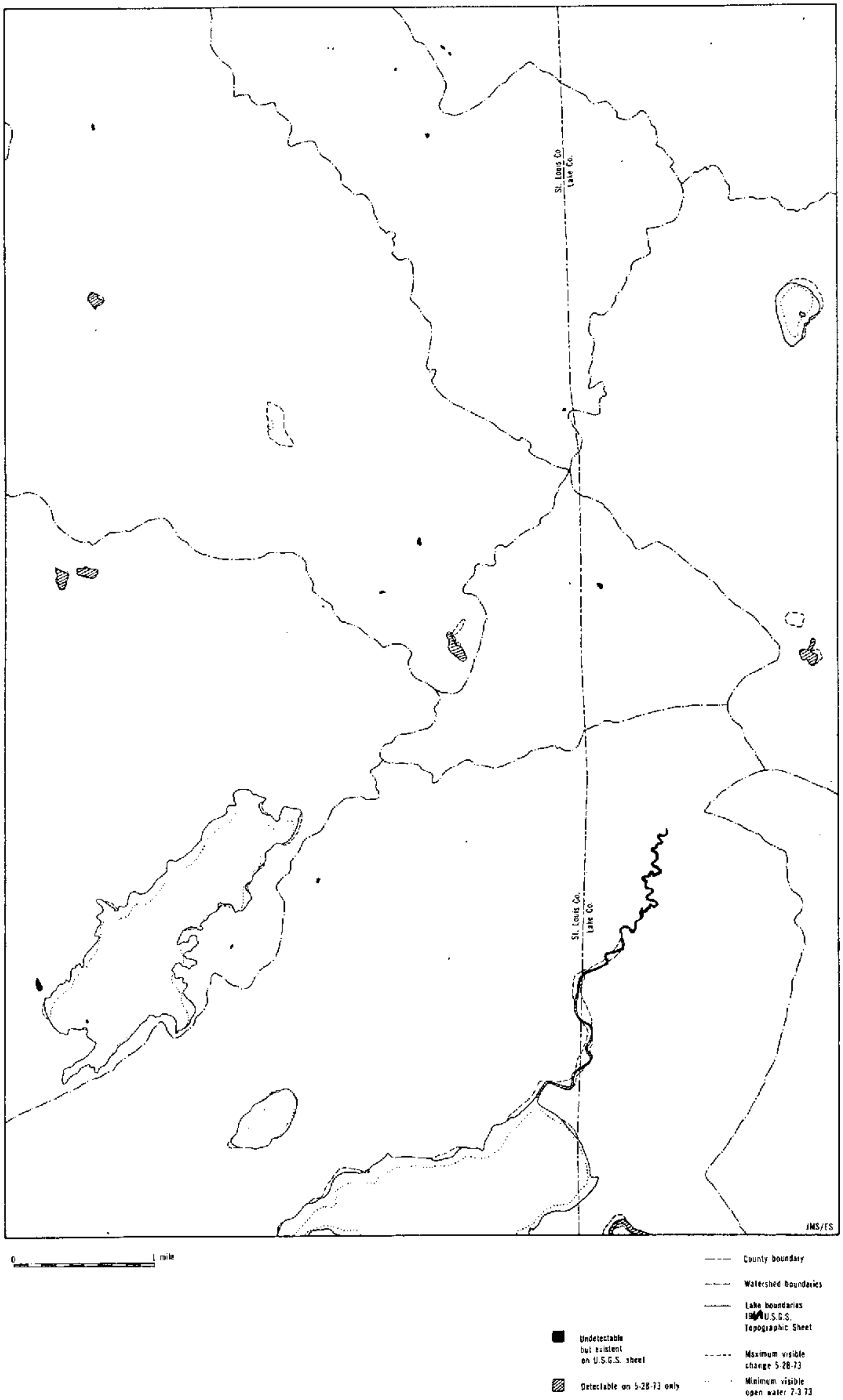
Detectable on 9-18-72 only

Minimum visible open water 7-21-73

Figure 9.

BABBITT SE QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

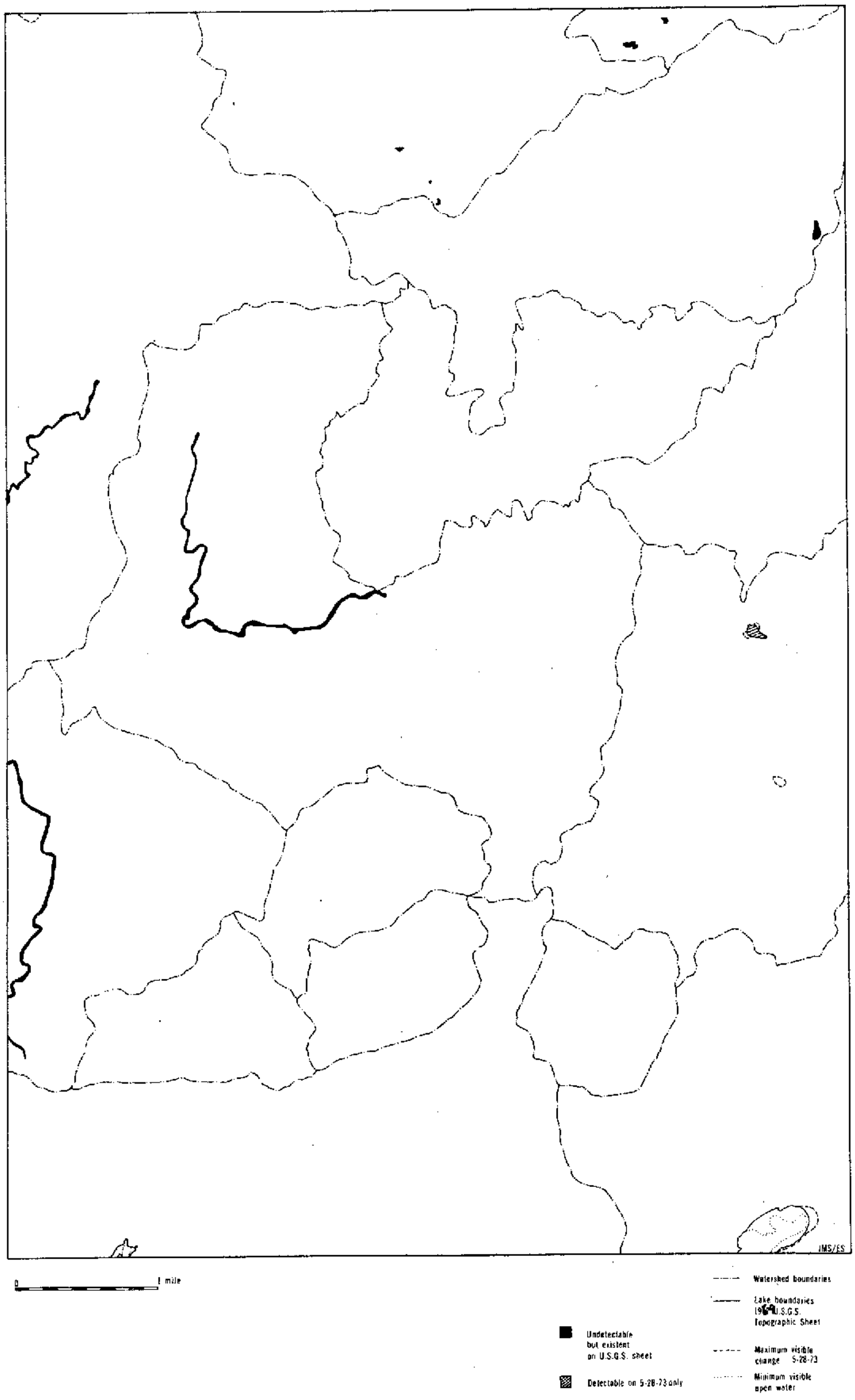


Source ERTS Satellite photographs

Figure 10.

BABBITT SW QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

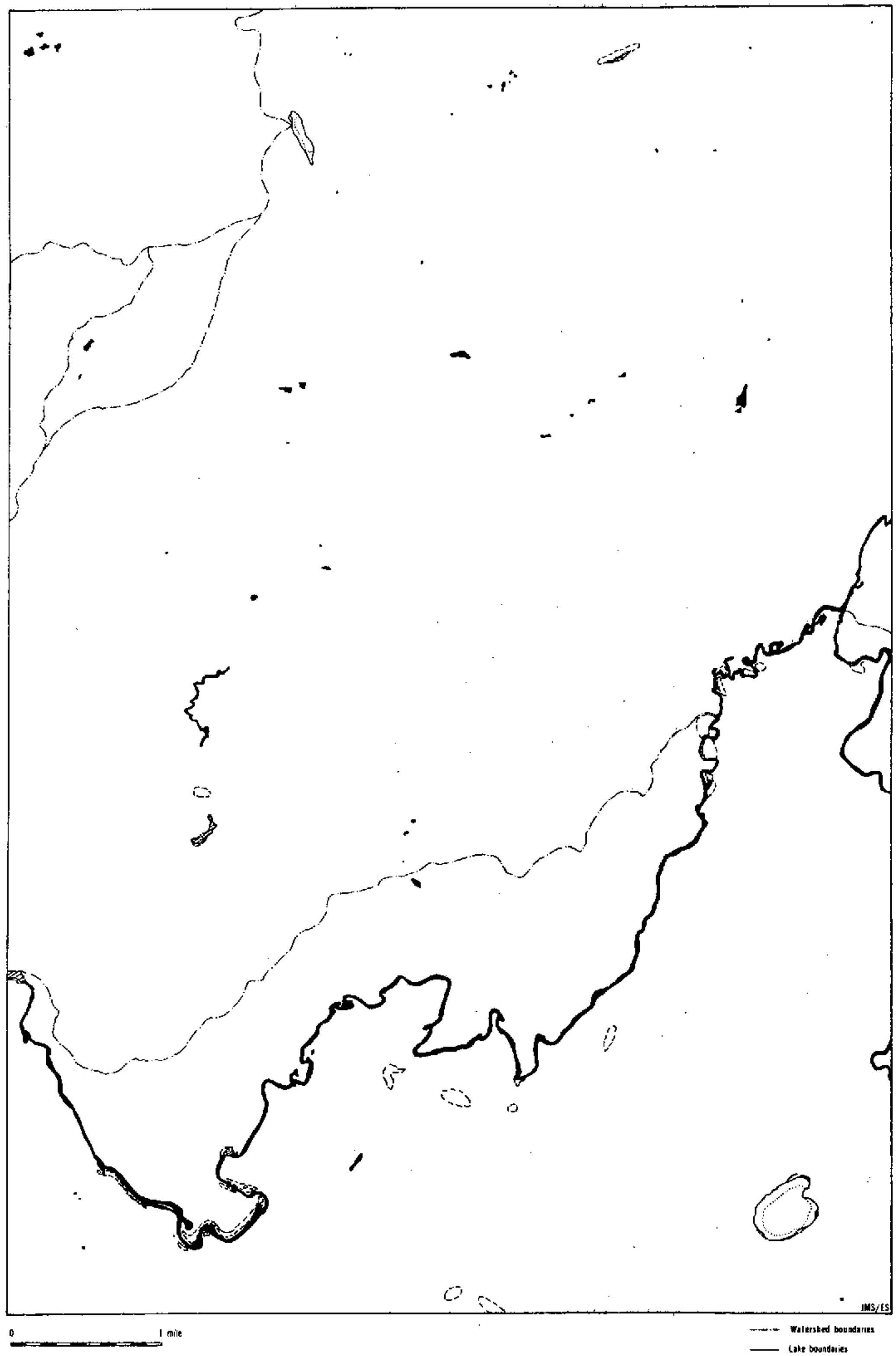


Source: ERIS Satellite photographs

Figure 11.

ALLEN QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

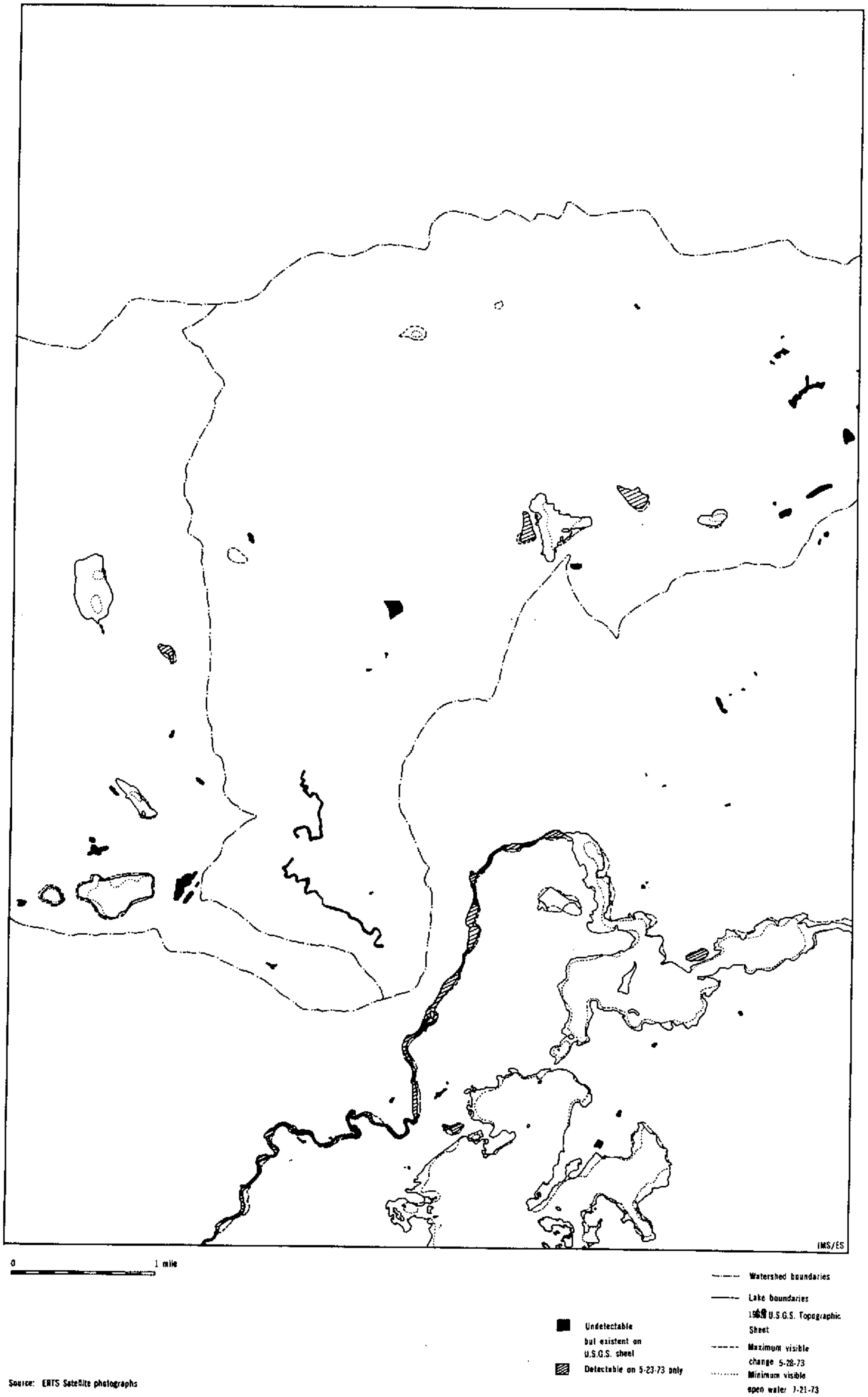


Source: ERIS Satellite photographs

Figure 12.

AURORA QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

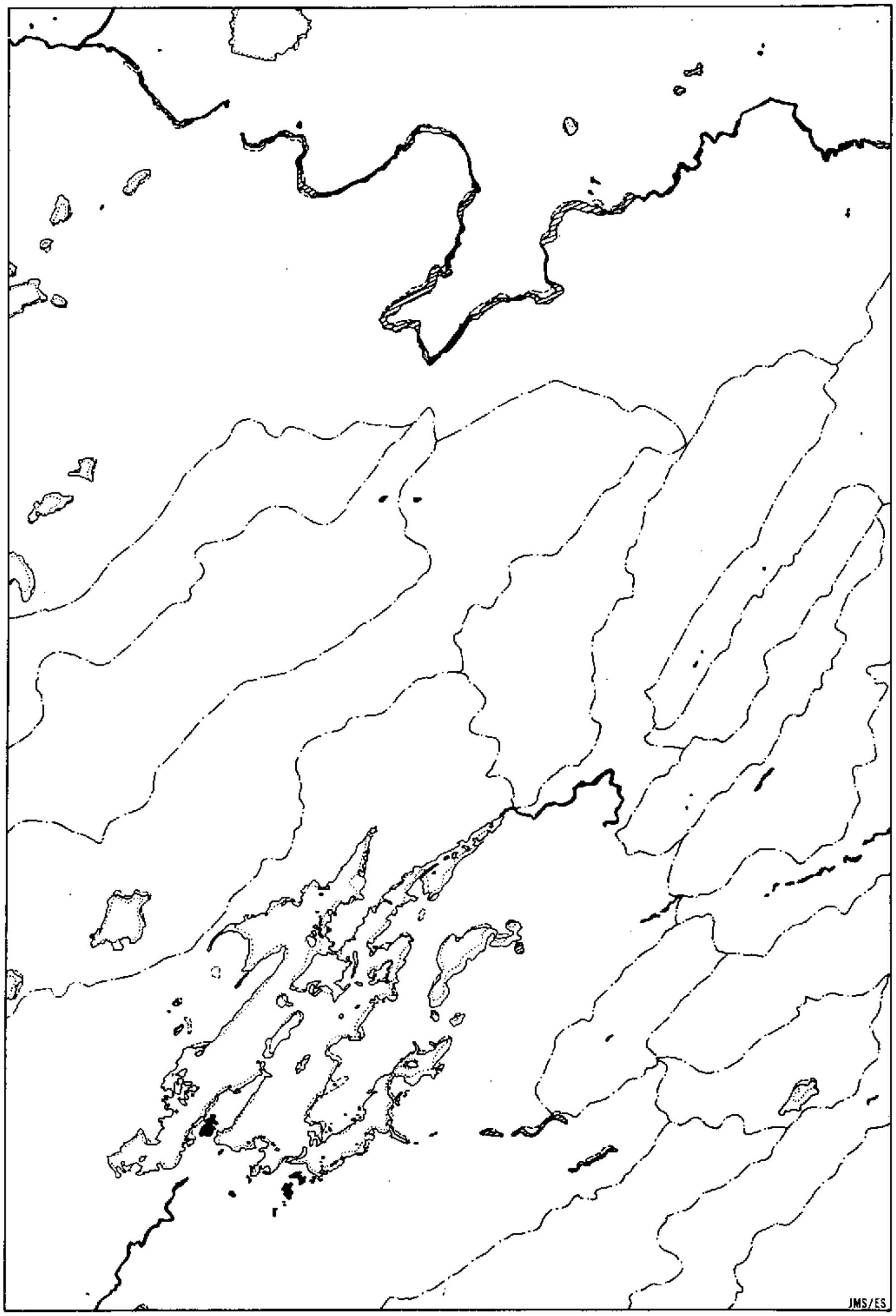


Source: ERTS Satellite photographs

Figure 13.

MARKHAM QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



1 0 1 mile

Watershed boundaries

Lake boundaries 19[illegible] U.S.G.S. Topographic Sheet

Undetectable but existent on U.S.G.S. sheet

Maximum visible change 9-18-72

Minimum visible open water 7-21-73

Detectable on 9-18-72 only

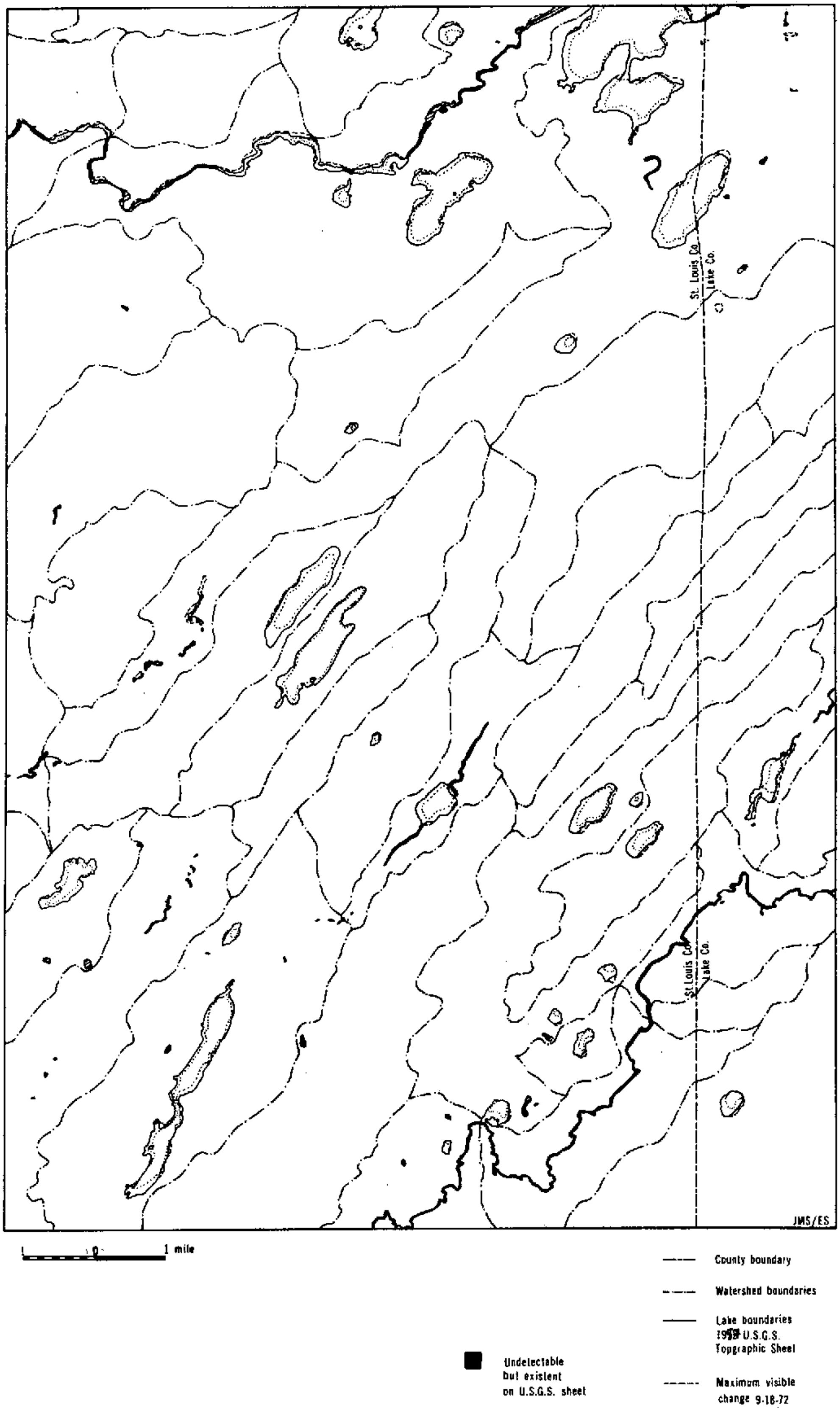
Source: ERTS Satellite photographs

Figure 14.

ORIGINAL PAGE IS OF POOR QUALITY

BRIMSON QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

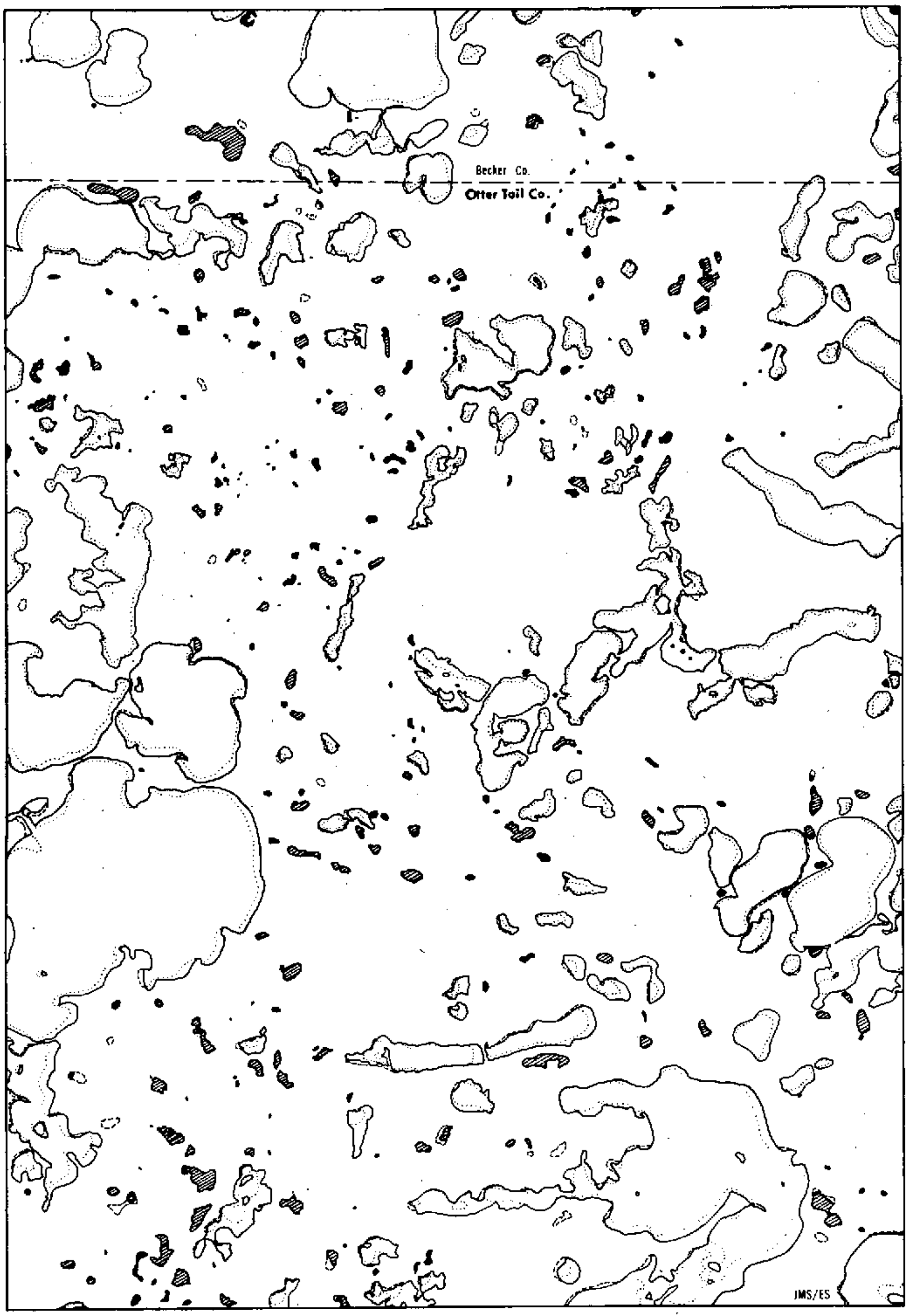


Source: ERTS Satellite photographs

Figure 15.

VERGAS QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



0 1 2 mile

County Boundary

Watershed Boundaries

Lake Boundaries

1912 U.S.G.S.
Topographic Sheet

Maximum visible open water 6-30-74

Minimum visible open water 8-28-73

Undetectable but existent on U.S.G.S. sheet

Detectable on 6-30-74 only

Source: "ERTS MSS Imagery"

Figure 16.

PELICAN RAPIDS QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

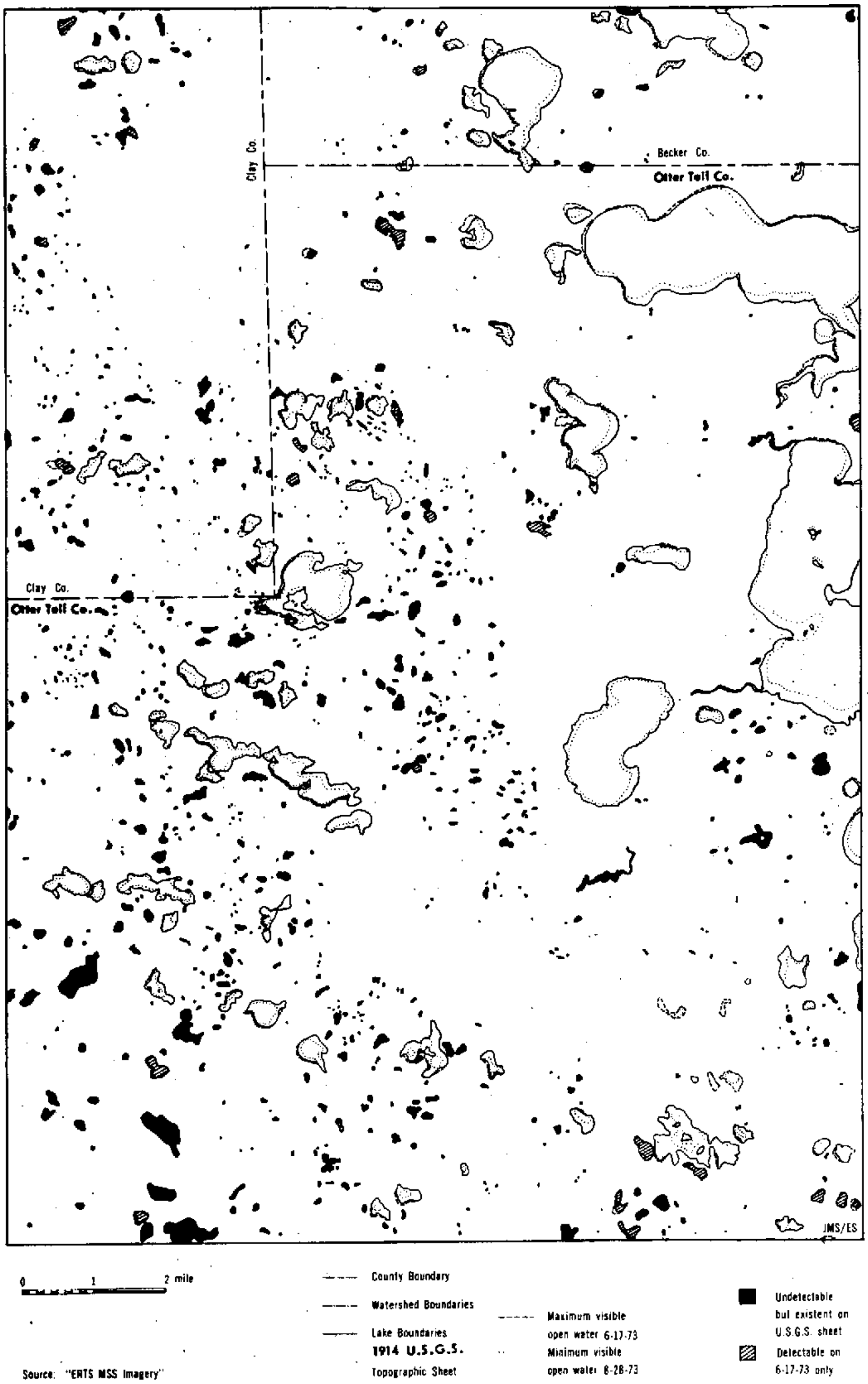
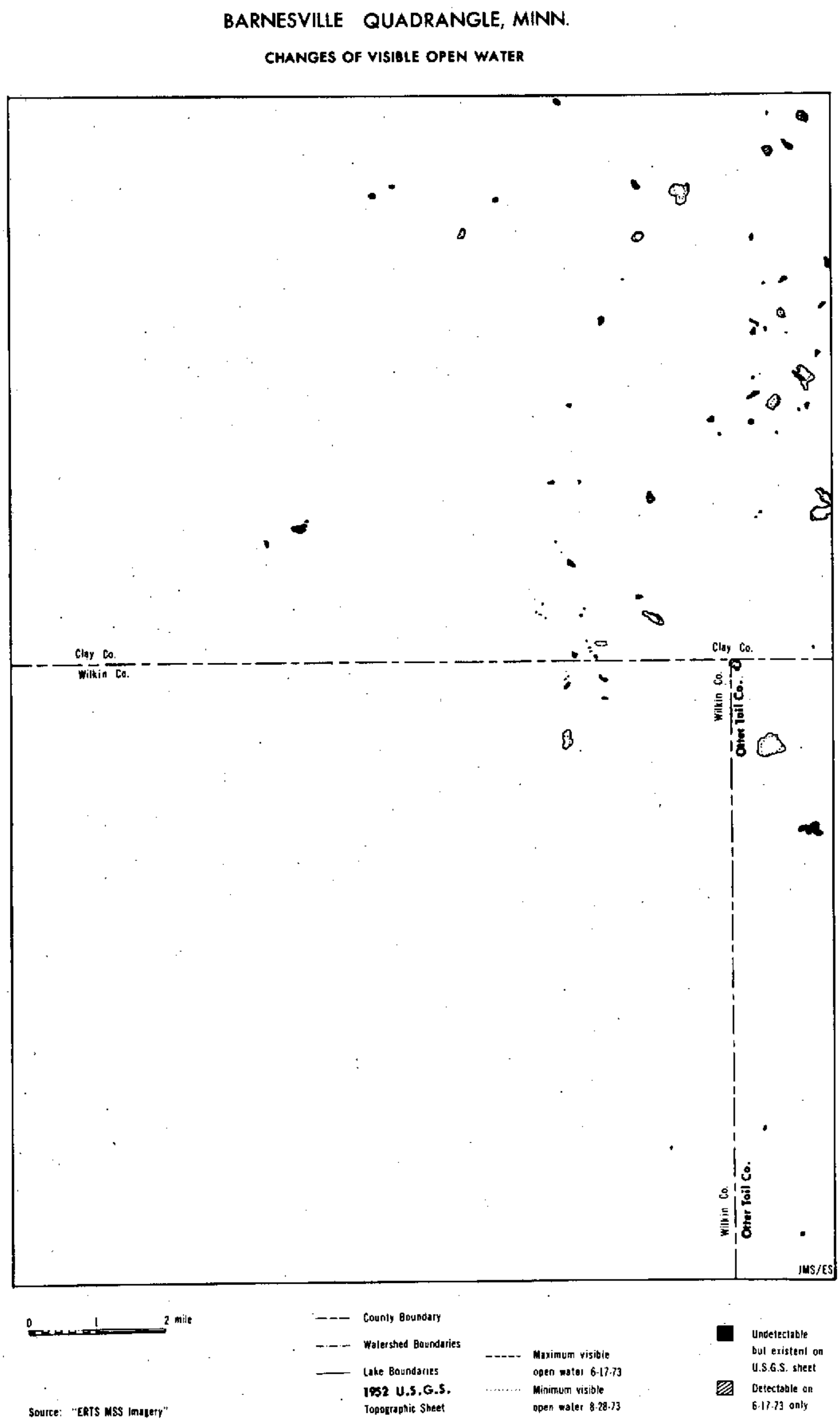


Figure 17.

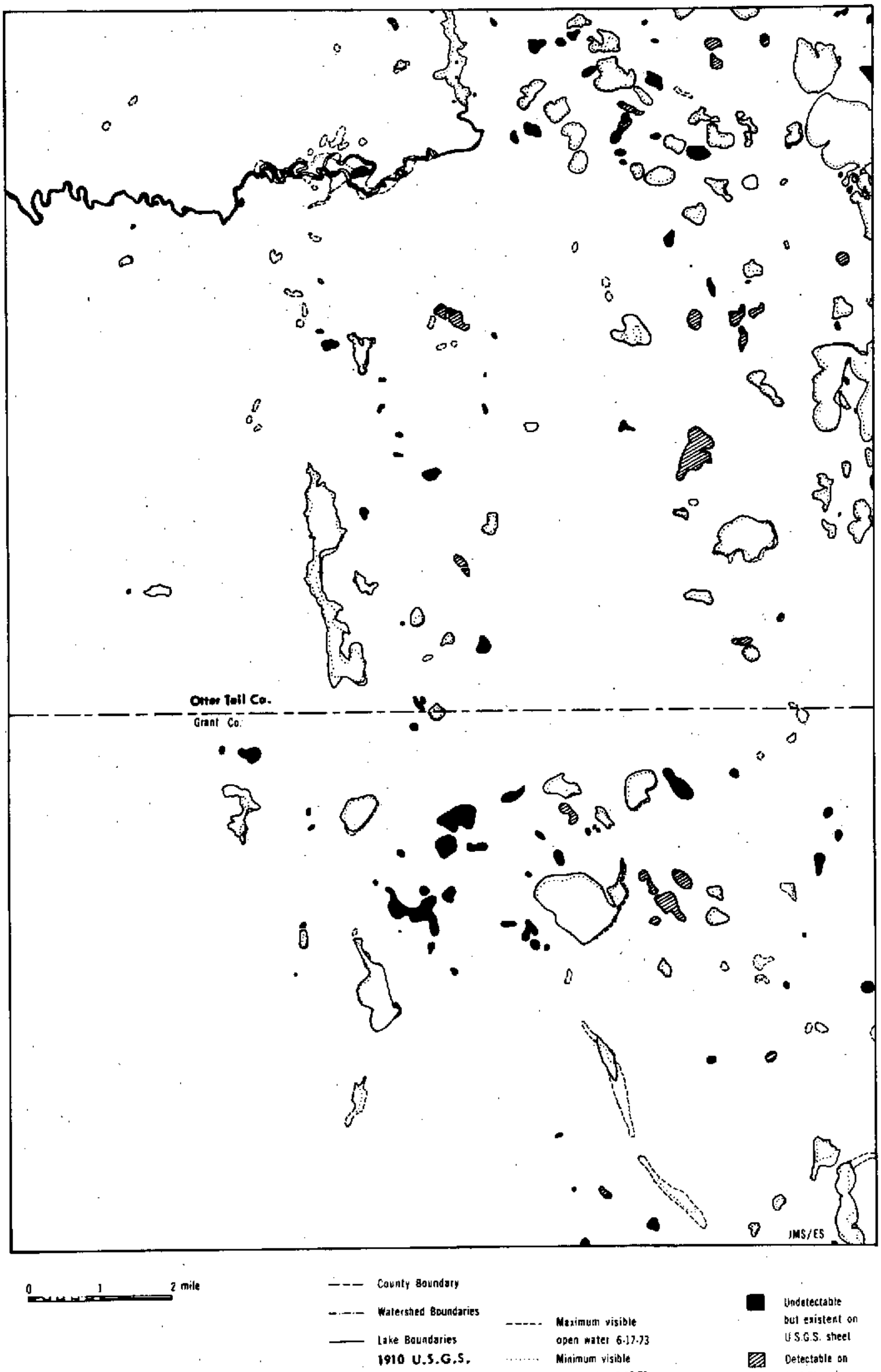


BARNESVILLE QUADRANGLE, MINN.
CHANGES OF VISIBLE OPEN WATER
Clay Co.
Wilkin Co.
Clay Co.
Wilkin Co.
Otter Tail Co.
Wilkin Co.
Otter Tail Co.
JMS/ES
0
1
2 mile
County Boundary
Watershed Boundaries
Lake Boundaries
1952 U.S.G.S.
Topographic Sheet
Maximum visible
open water 6-17-73
Minimum visible
open water 8-28-73
Undetectable
but existent on
U.S.G.S. sheet
Detectable on
6-17-73 only
Source: "ERTS MSS Imagery"

Figure 18.

WENDELL QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



Source: "ERTS MSS Imagery"

Figure 19.

CHOKIO QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

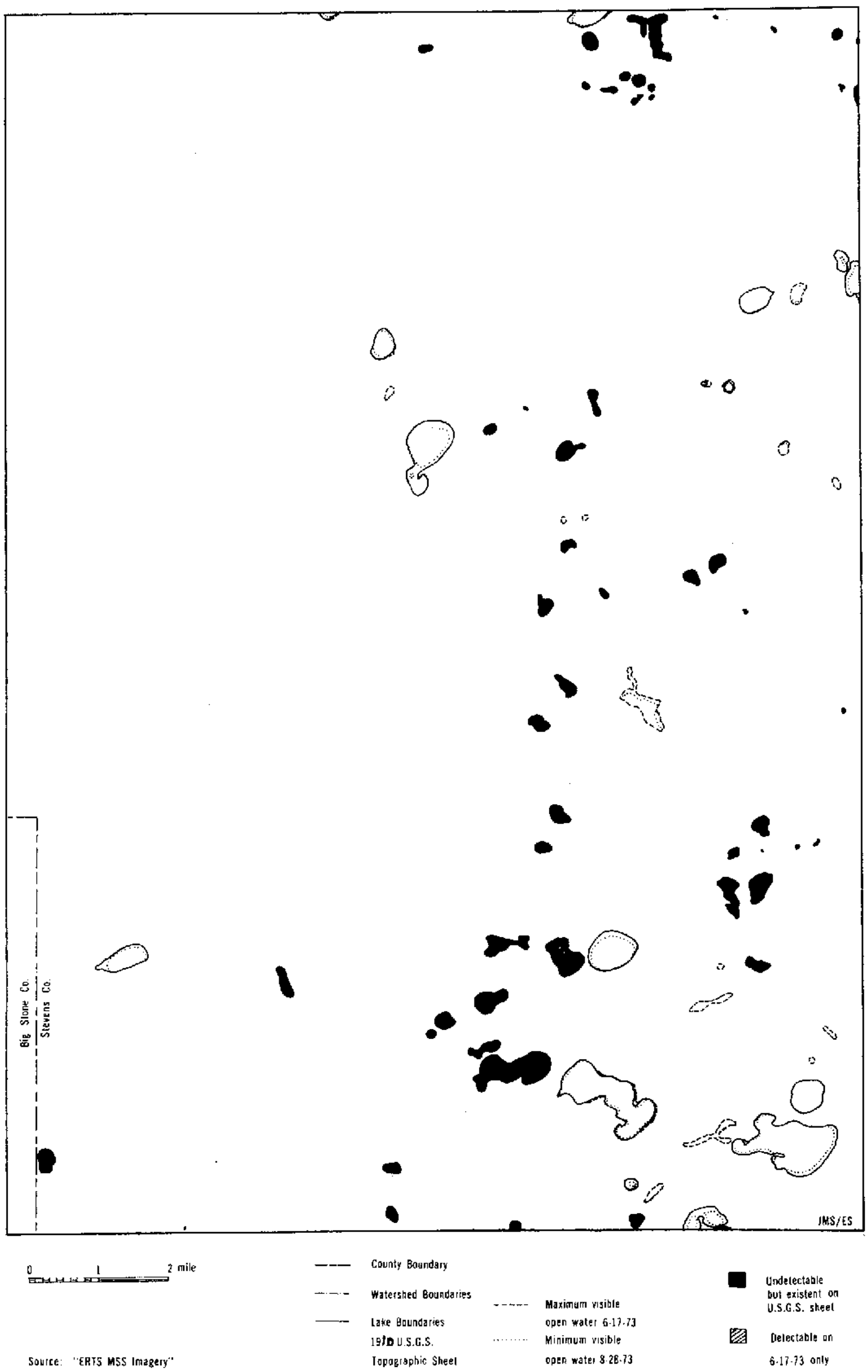


Figure 20.

TAUNTON QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

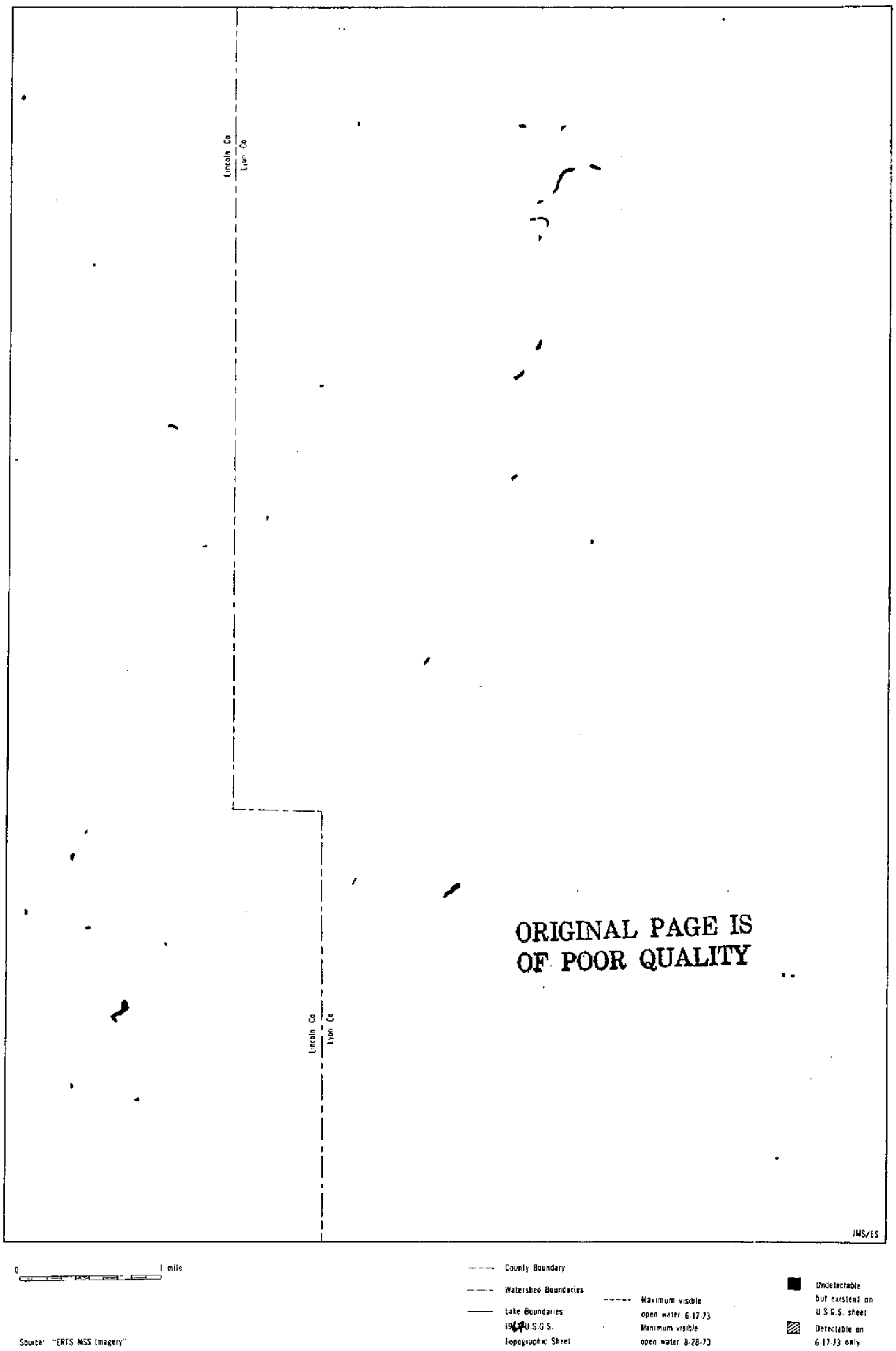


Figure 21.

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OF POOR QUALITY

PORTER S.W. QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

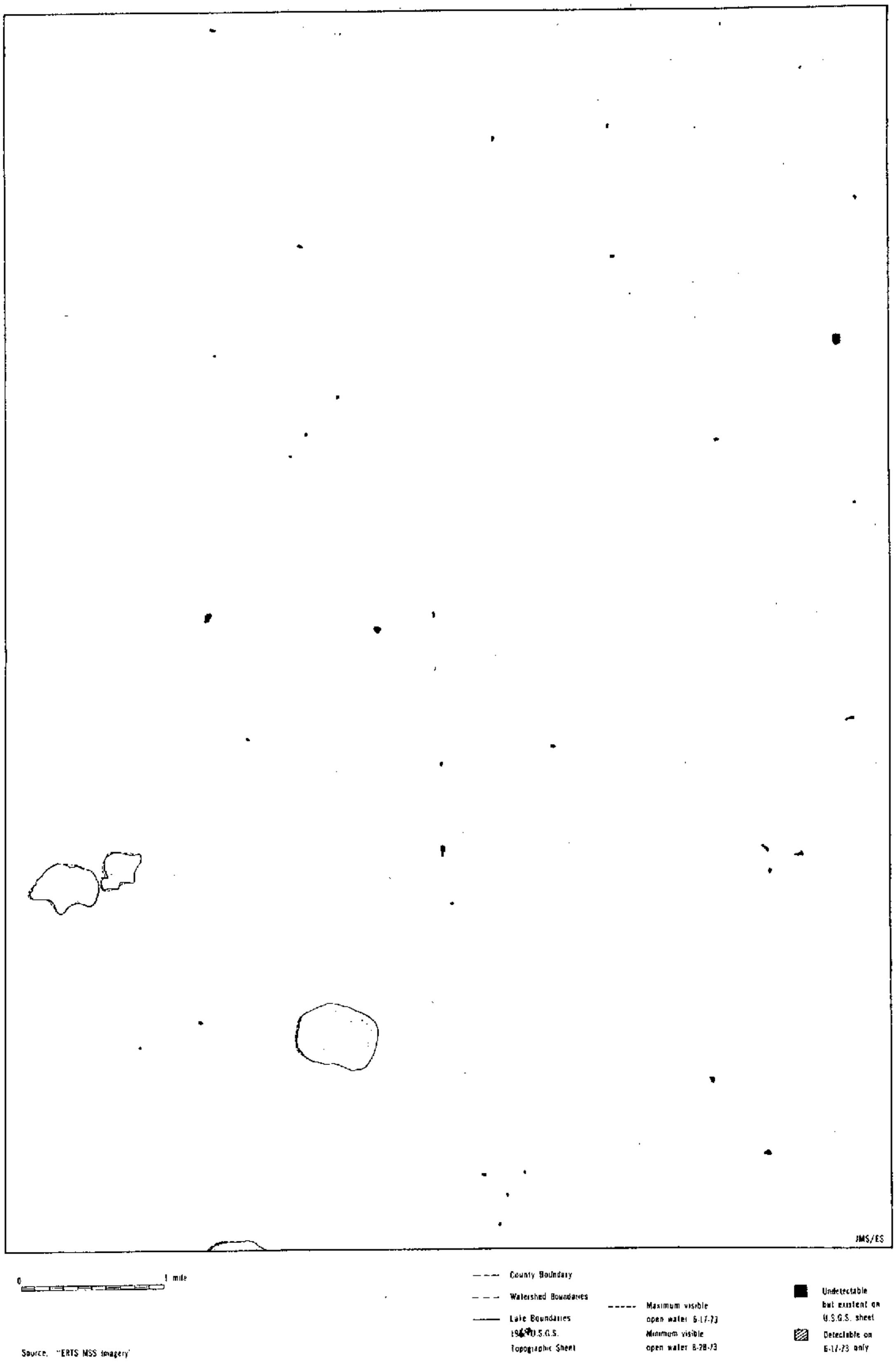


Figure 22.

CANBY S.E. QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

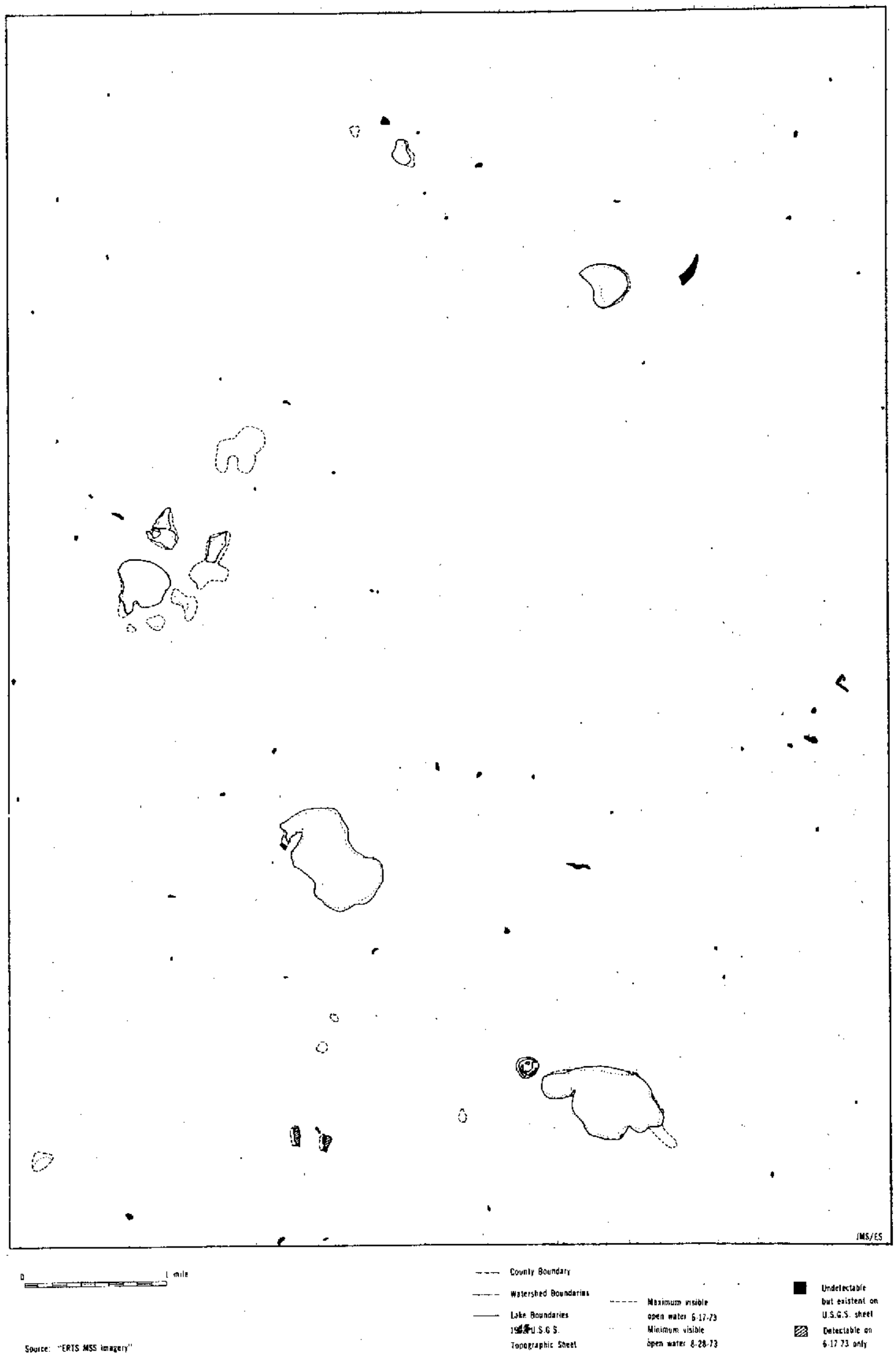
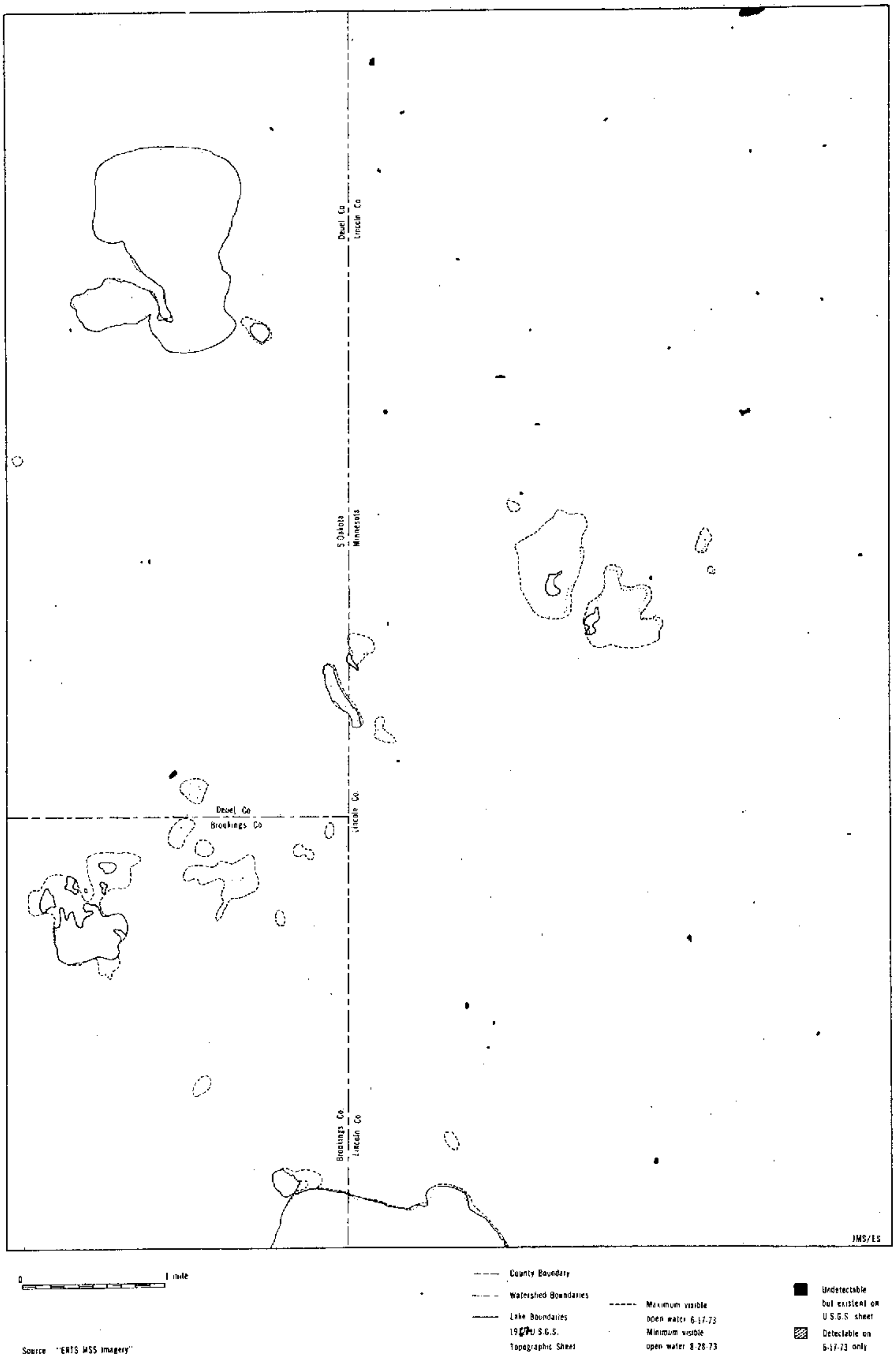


Figure 23.

HENDRICKS QUADRANGLE, MINN. -S. DAKOTA

CHANGES OF VISIBLE OPEN WATER



Source "ERTS MSS Imagery"

Figure 24.

LAKE BENTON N.W. QUADRANGLE, MINN.-S.DAKOTA

CHANGES OF VISIBLE OPEN WATER

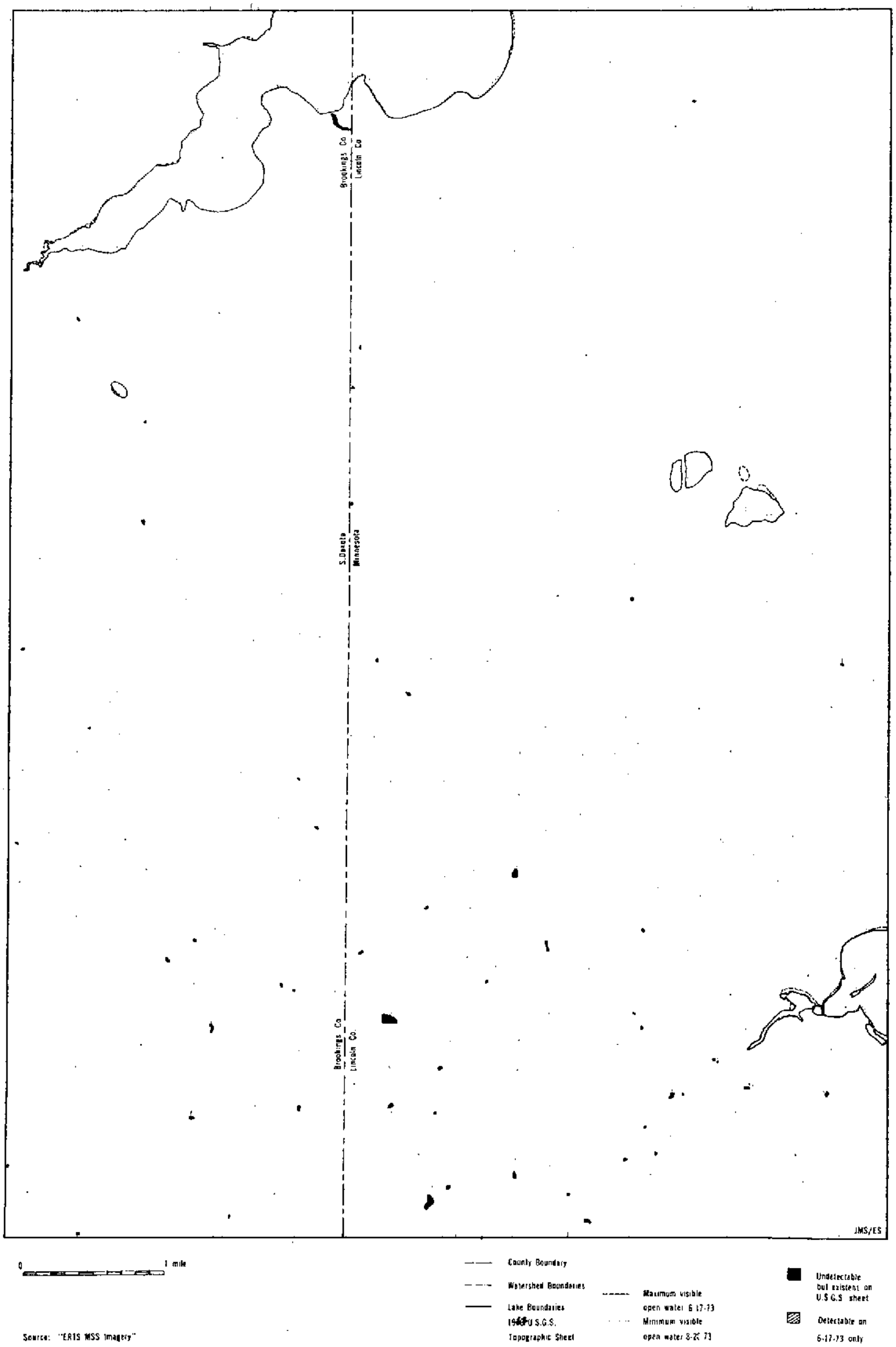


Figure 25.

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OF POOR QUALITY

LAKE BENTON N.E. QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

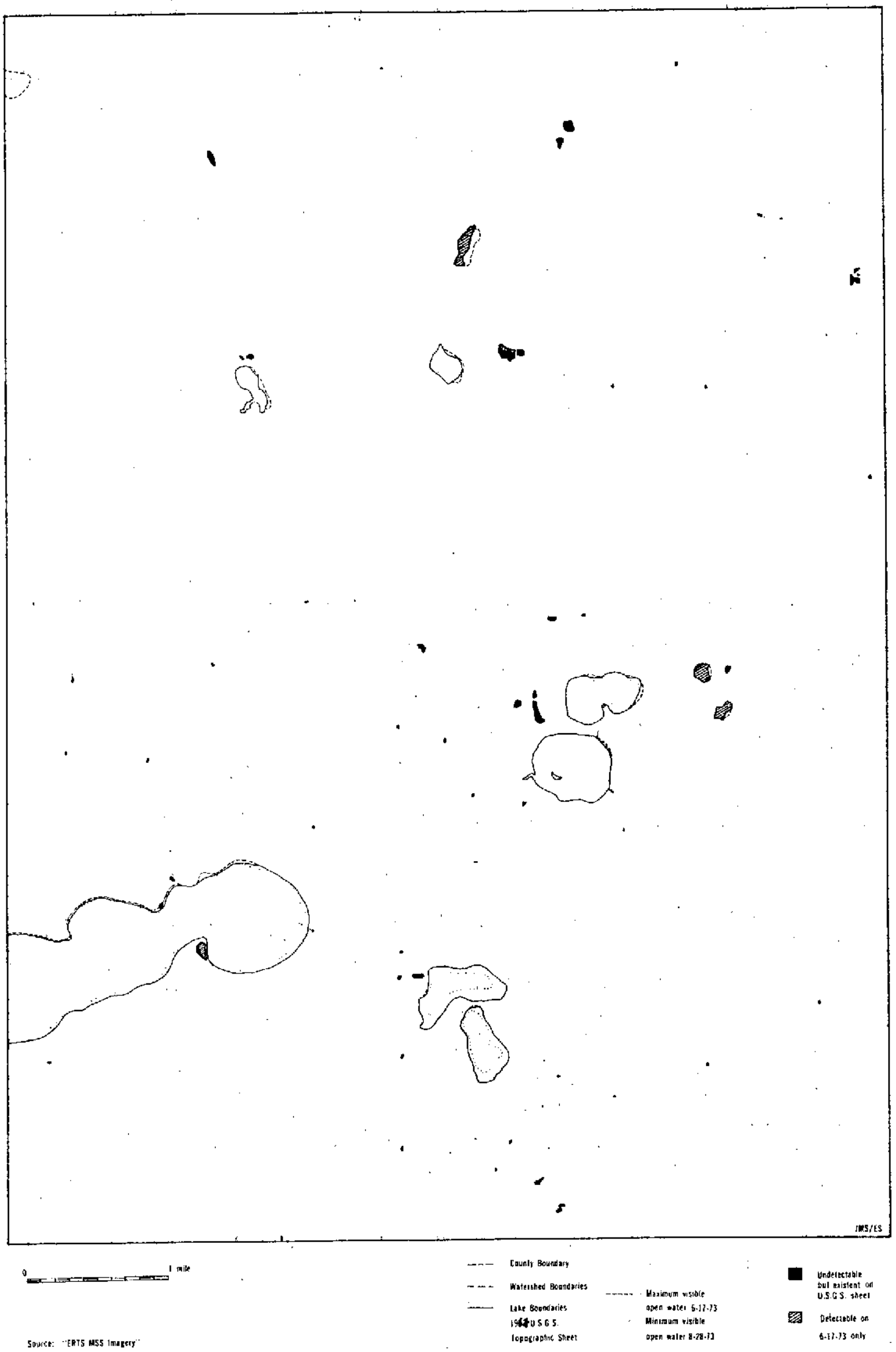

Figure 26.

ARCO QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

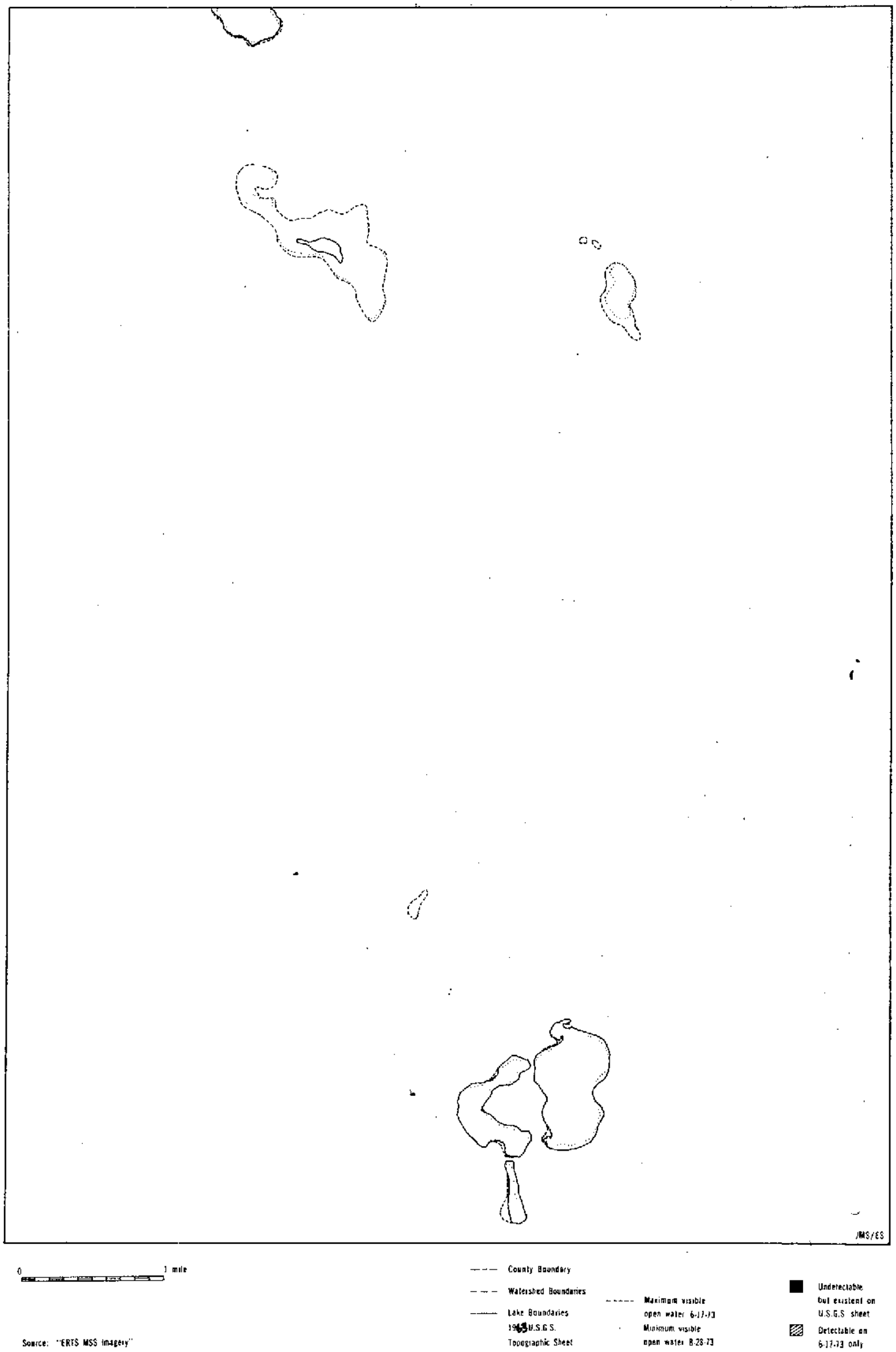

Figure 27.

GISLASON LAKE QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

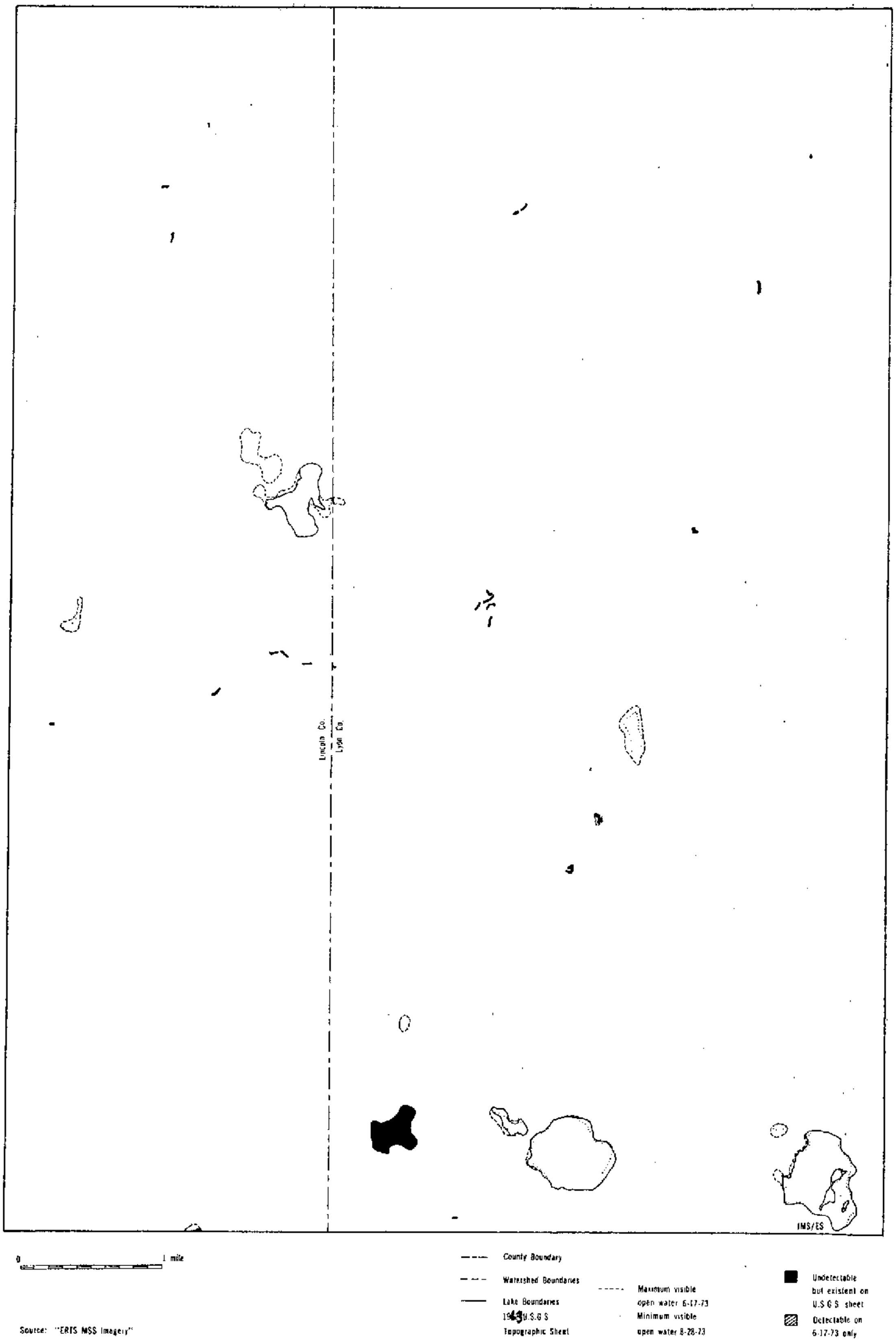

Figure 28.

DEAD COON LAKE QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

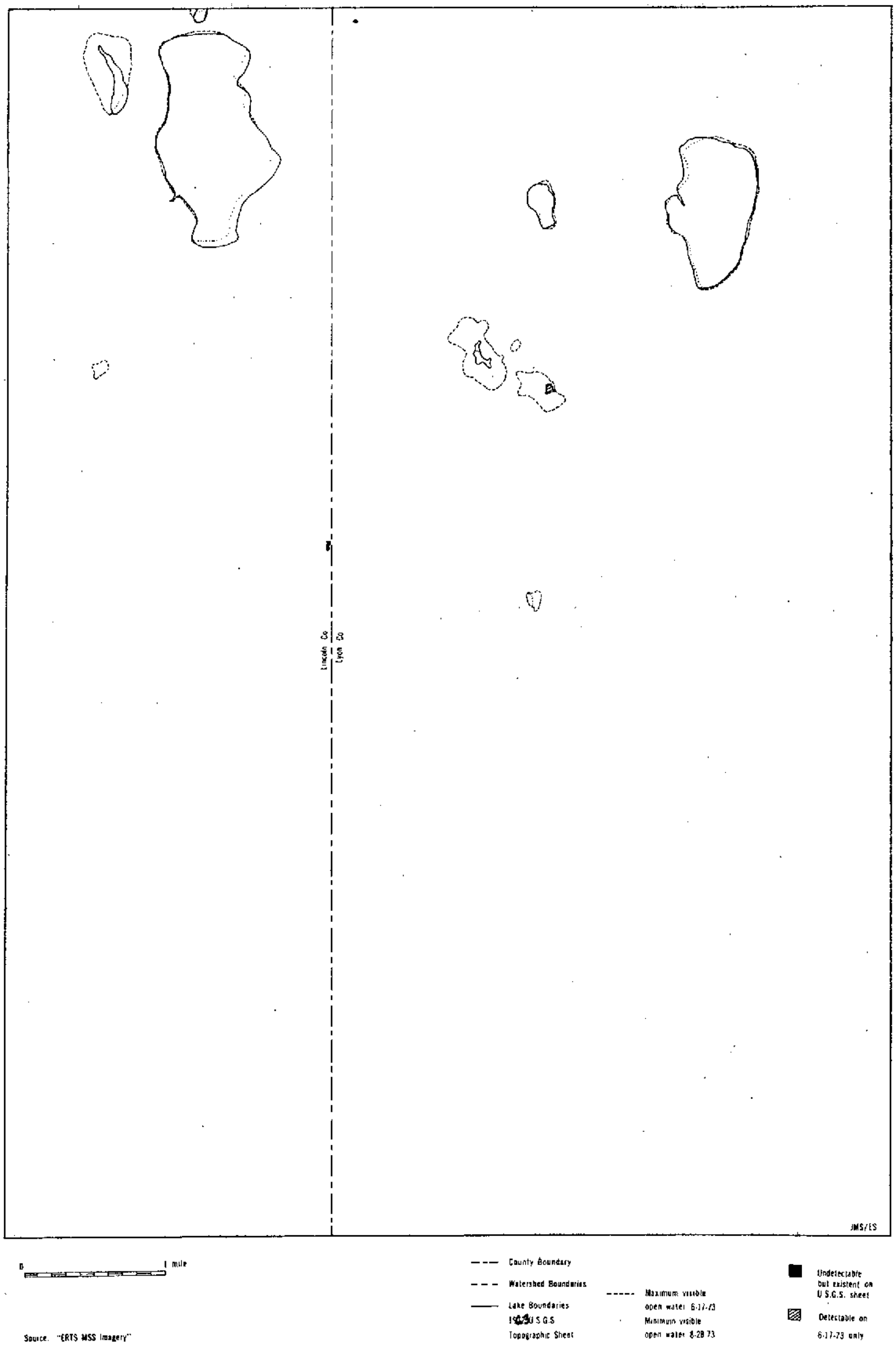

Figure 29.

TYLER QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

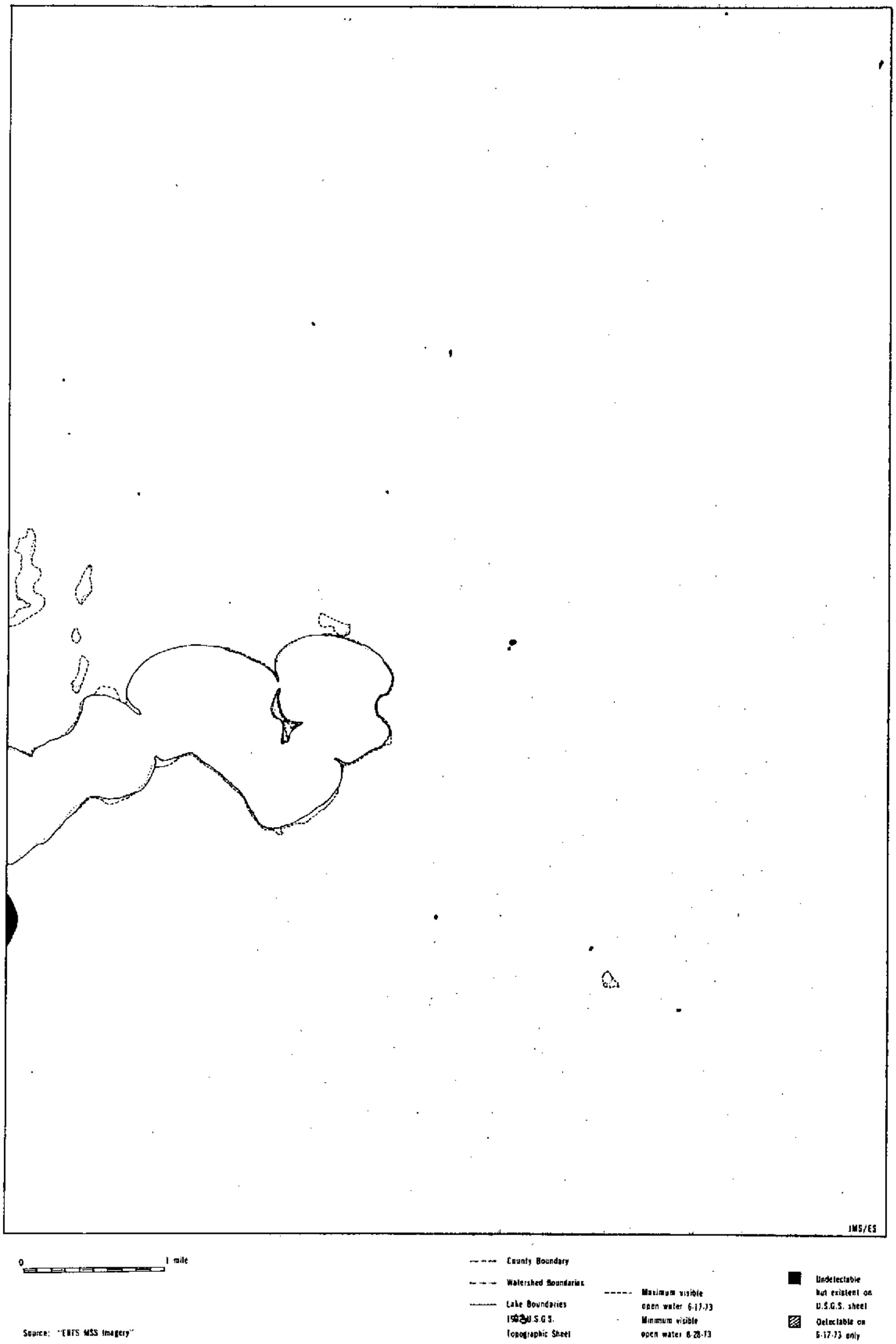

Figure 30.

LAKE BENTON QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

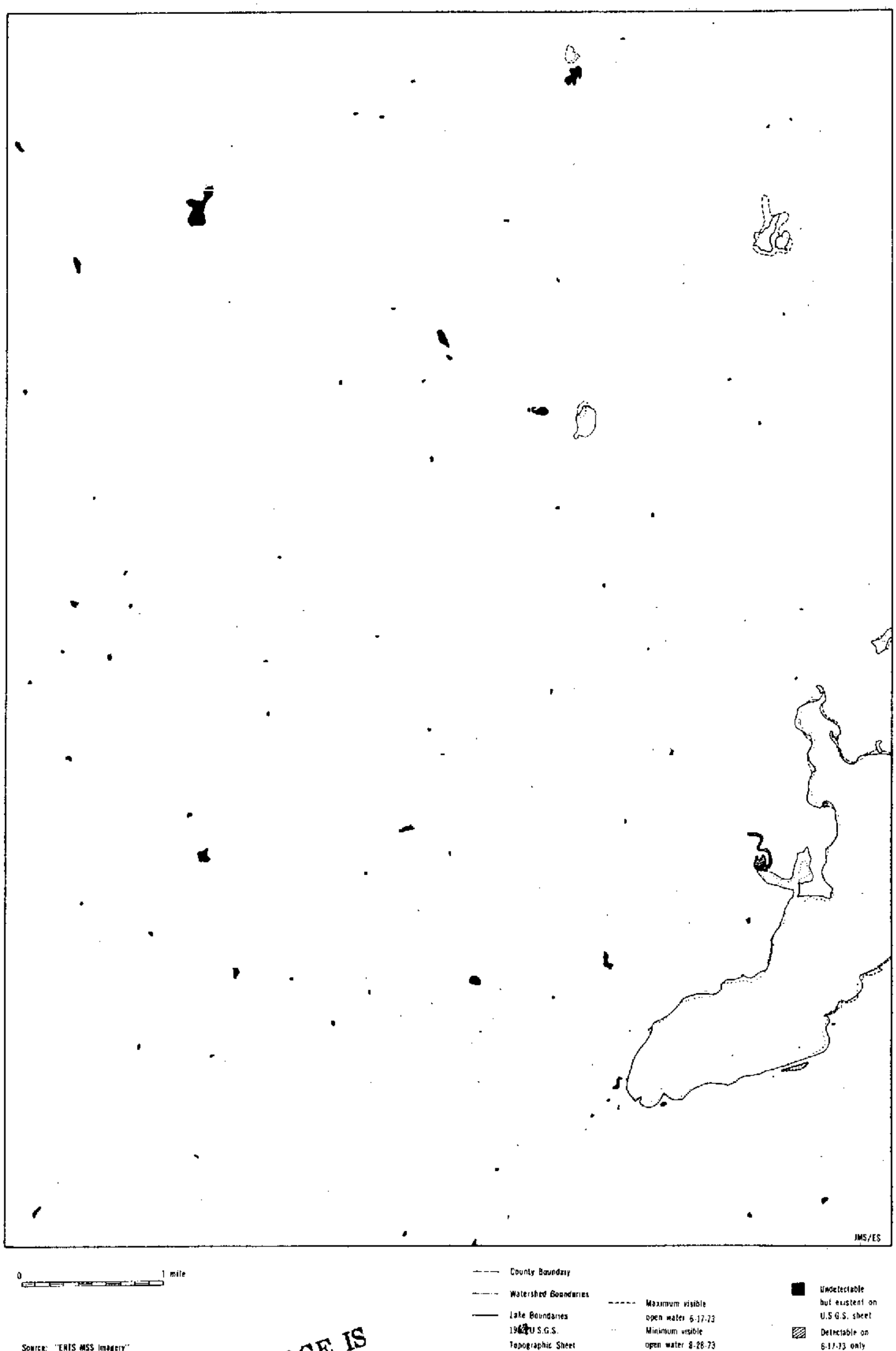

Figure 31.

LAKE BENTON S.W. QUADRANGLE, MINN. -S. DAKOTA

CHANGES OF VISIBLE OPEN WATER

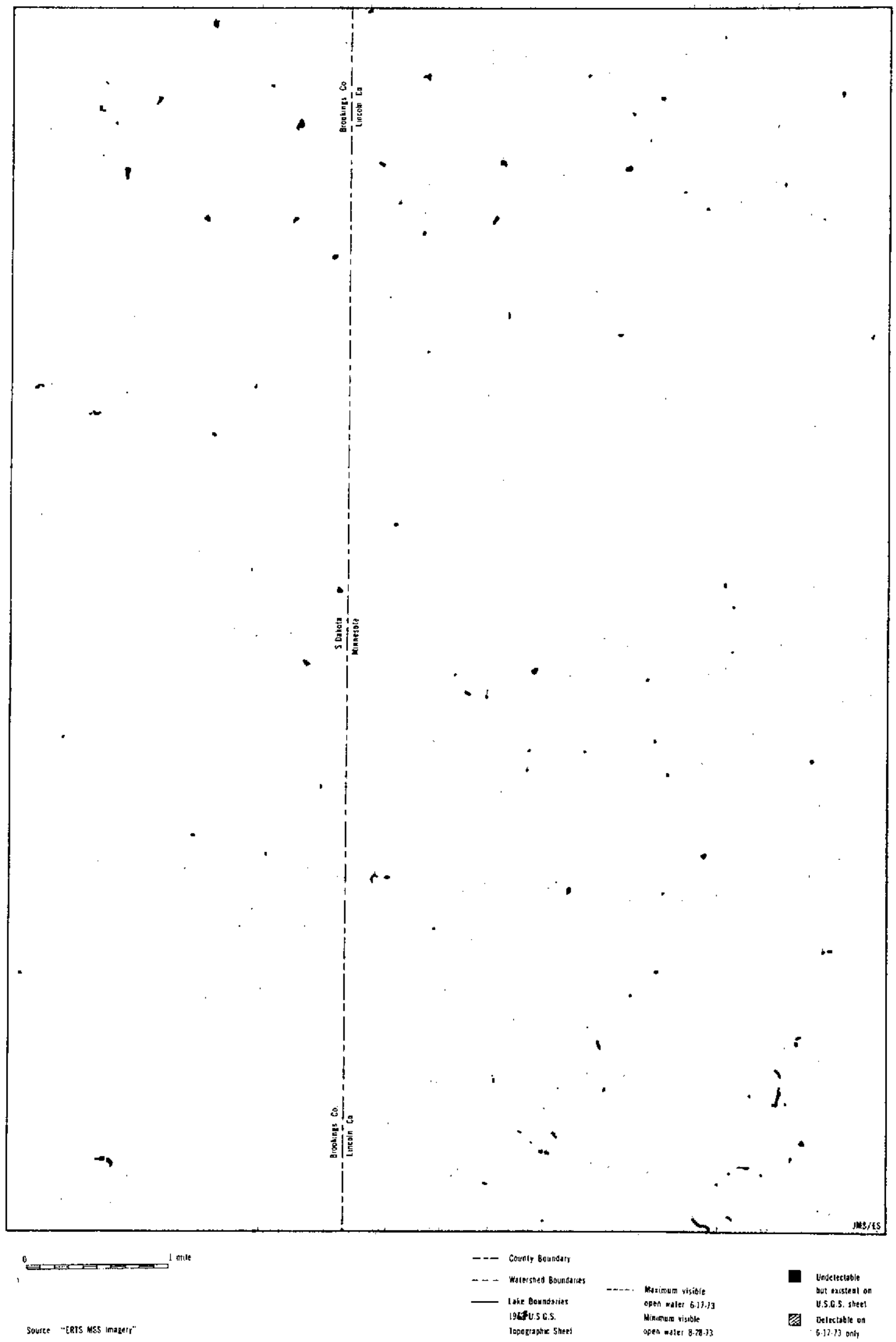

Figure 32.

ELKTON QUADRANGLE, MINN.-S. DAKOTA

CHANGES OF VISIBLE OPEN WATER

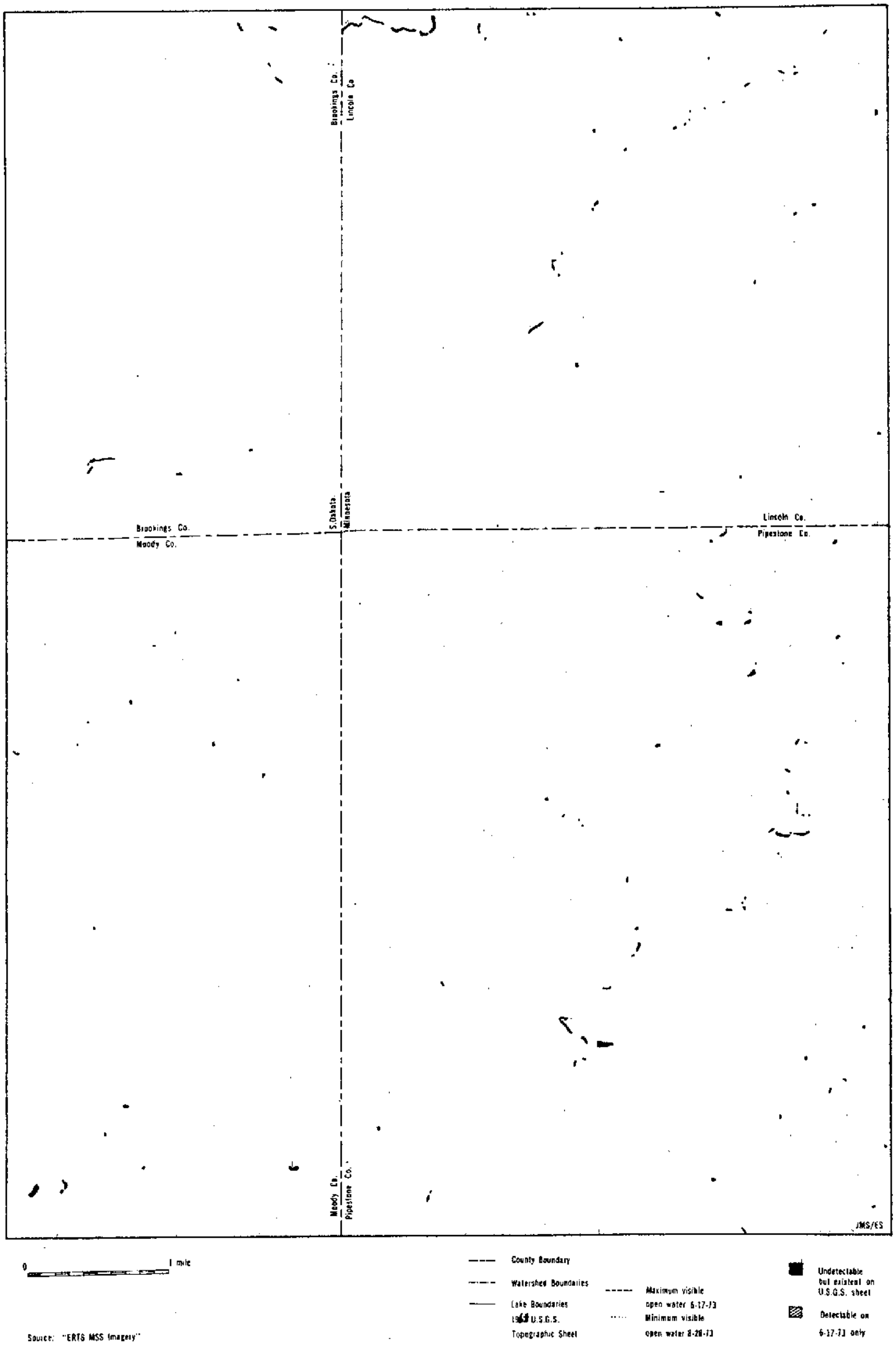

Figure 33.

VERDI QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

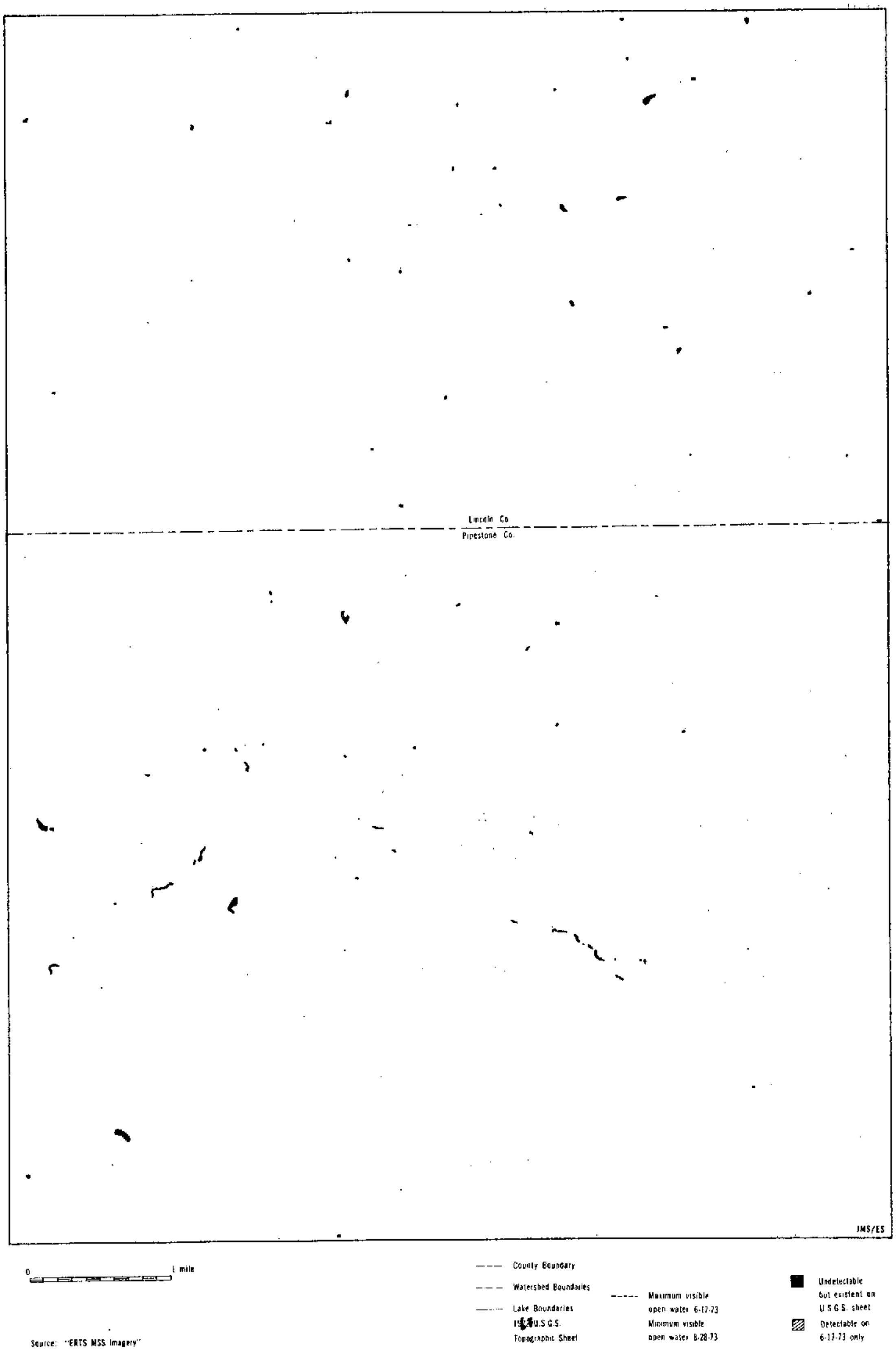

Figure 34.

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OF POOR QUALITY

RUTHTON N.W. QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER

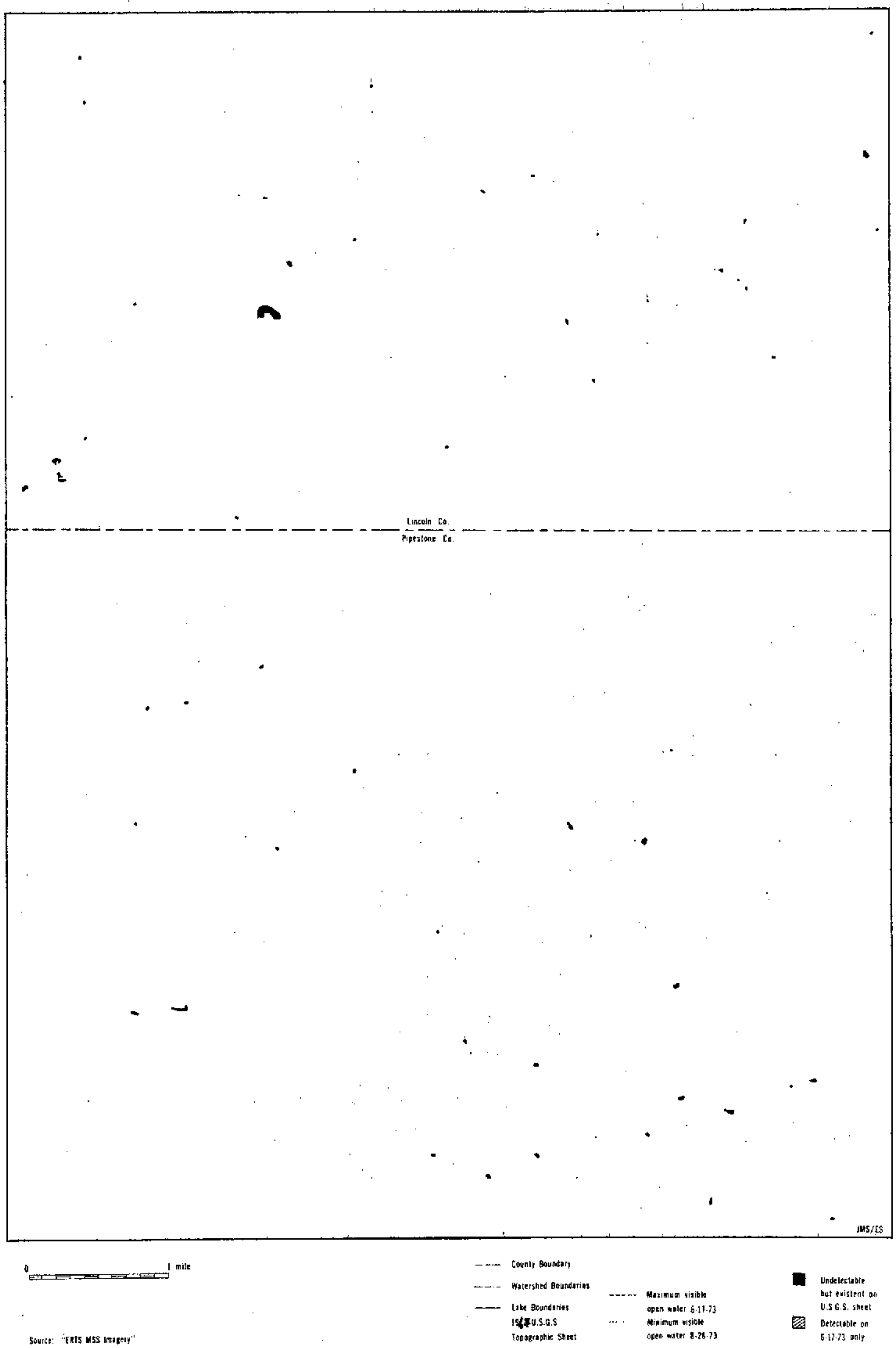
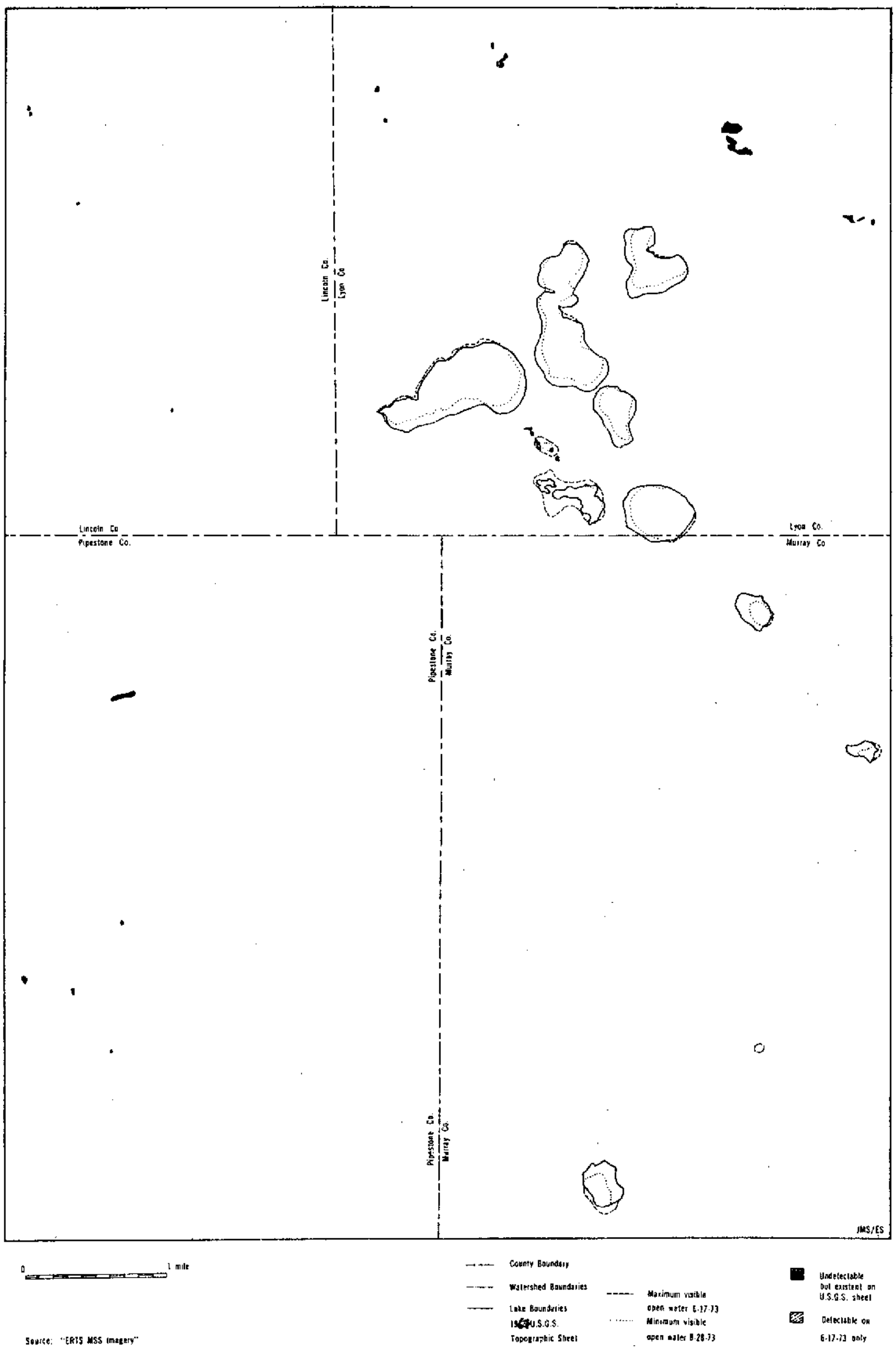


Figure 35.

RUTHTON QUADRANGLE, MINN.

CHANGES OF VISIBLE OPEN WATER



Source: "ERTS MSS imagery"

Figure 36.

described above. It was deemed desirable to attempt to maximize the detail and include even the smallest open water bodies that are portrayed on topographic quadrangles. Secondly, the normal water levels, portrayed on the USGS quads, should be included and supplemented by information on the seasonal maximum water.

To satisfy the data requirements for this map, the 45 quadrangles for the 7 county Metropolitan Area were photographically reduced to 1:125,000 scale and mosaiced. It was considered desirable to eliminate the watershed boundaries and the seasonal minimum water extent shown on the quads, thus necessitating redrafting. The Metropolitan Minneapolis-St. Paul Area map in the map pocket shows the final product. The solid black areas shows the water indicated on topographic maps that was not detectable during the July 1972-July 1974 period of ERTS coverage. Many of the smaller water bodies shown in black are too small for detection by ERTS. Those lakes greater than 10 acres shown in black should be seen with a high degree of reliability with ERTS-1 images and can be considered to lack open water surface during the times of data collection by the satellite. The blue pattern extending beyond the black normal water line indicates seasonal inundation interpreted from ERTS-1 images.

COST PROJECTIONS

The experience gained in producing the quadrangles shown in Figures 3-36 and the 45 quads used to produce the Metropolitan Minneapolis-St. Paul Area map indicates that the cost of producing quadrangle overlays varies significantly throughout the state. Labor for the complete maps ranges from 5.25 to 22.25 man hours. Labor requirements are generally higher in areas with many or highly irregular lakes. The 1:62,500 (15') series quads are more expensive than the 1:24,000 (7.5') series; but, of course they individually cover 4 times more area. There are approximately 425 15' quad areas in Minnesota, mostly mapped in the 7.5' series. The labor required for each 15 minute area averages about 25

hours or a total of 10,625 man hours to complete the entire state.

Supply costs would run approximately $50 per 15' area or about $21,250 for the state. Equipment costs would be under $2,000 for an operation large enough to complete the job in one calendar year.

Labor requirements for the Metropolitan Minneapolis-St. Paul Area map in the pocket were 180 hours. The cost includes mosaicing the 45 reduced quadrangles, drafting the two plates for the printer, and editing the proof. The 180 hours by this method seems quite high in comparison with the 30 hours for the county maps interpreted directly from ERTS-1 70mm positives of band 7. It must be remembered that the direct mapping process included only one piece of information, was lower in locational accuracy, did not contain topographic map data, and did not include many lakes smaller than 20 acres.

EVALUATION

Comparison of verified surface water topographic maps with Bulletin 25 yields a multitude of discrepancies when compared on a lake by lake basis for the seven county metropolitan area. The data for this comparison are shown in Table 1. Because of the 10 acre limit in Bulletin 25 only water features of that size are considered here. It should be pointed out that Bulletin 25 is an inventory of basins capable of holding water and not of water area. It has annotations for basins that are affected by drainage, partially dry, and dry at the time of the aerial photography used in the inventory.

The first column of Table 2 indicates the number of 10 acre or larger lakes detected on ERTS-1 for which there were no basins listed in Bulletin 25. These lakes probably represent enlargements of small lakes missed because of their condition on single season aerial photography, dominantly taken during prolonged dry periods. The 126 lakes for the 7 county area does indicate a 13% increase in the number of basins. The third and fourth column indicate the

TABLE 1. Comparison of Twin Cities Metropolitan Area Map with an Inventory of Minnesota Lakes, Bulletin 25

County	Mapped Lakes ≥ 10 Acres not in Bulletin 25	Number of Basins in Bulletin 25	Mapped Lakes ≥ 10 Acres Listed in Bulletin 25 as Not Affected by Drainage or Dry		Mapped Lakes ≥ 10 Acres Listed in Bulletin 25 as Affected by Drainage or Dry			
			Reduced in Size	Empty Basins	Total Listed	Affected but Wet	Reduced in Size	Empty Basins
Anoka	15	143	1	6	55	31	7	17
Carver	30	128	0	1	73	25	5	43
Dakota	16	83	2	1	8	2	0	6
Hennepin	32	200	2	12	39	18	3	18
Ramsey	14	82	4	1	31	6	6	9
Scott	14	144	0	6	92	36	3	53
Washington	5	168	1	6	6	3	1	2
Metropolitan Area Total	126	948	10	33	304	121	25	148

number of lakes that are reduced in size or dry and are not so indicated in Bulletin 25. Column 5 shows the number of basins listed in Bulletin 25 as affected by drainage and dry and column 6 indicates how many of these affected basins had significant water areas at some time during the period of ERTS coverage from August 72 through July 74. Columns 7 and 8 indicate the reduced and empty status of basins reported as affected by drainage.

Similar comparison for the 1912 vintage 1:62,500 scale Chokio Minnesota Quadrangle (Stevens Co.) indicates that only 20 of the 118 lakes over 10 acres were detectable on ERTS-I images. Sixty four basins in Bulletin 25 were not indicated with water on the 1912 quadrangle. One additional lake on the quad was not included in either Bulletin 25 or on the ERTS imagery. The portions of 16 1:24,000 scale quadrangles that cover Lincoln County contain 9 lakes detected from ERTS-I images that are neither on the quads nor in Bulletin 25. Of the 118 Lincoln Co. basins included in Bulletin 25, 66 are not present on the ERTS verified quadrangles.

Differences between Bulletin 25 and ERTS verified water maps stem largely from two factors. First is the use of existing areal photography to map basins. Available aerial photography, at the time Bulletin 25 was being compiled, was single season and seldom taken in the spring, the normal period of maximum water. Second is the age of the existing aerial photography used. Some photography is now over 30 years old, and for some counties, it was taken during prolonged dry periods. The photography used for the Metropolitan 7 county area in this evaluation is now 21-25 years old. These products placed severe limitations on the mapping of seasonally wet basins and their age may account for considerable changes resulting from manipulation of basins.

CONCLUSIONS

The findings of this research indicate that ERTS-1 products

can serve as a low cost extender of existing and topographic maps and photography for examining seasonal variations in visible open surface water. The ERTS-I materials alone are capable of providing rapid reconnaissance analysis of open surface water resources. Coupled with good topographic quadrangles, the interpretation of surface water from ERTS-1 images can provide far more detailed surface water information than now exists in Minnesota for lakes larger than 5 acres. Smaller water bodies are not detectable with any reasonable degree of reliability and other data sources must be sought where these water features are of concern.

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Prestin, Steven J., 1974, Management of Hydrographic "Features in West-Central Minnesota from ERTS-1 Imagery": A Study of Minnesota Forests and Lakes Using Data from Earth Resources Technology Satellites, Space Science Center, University of Minnesota, p. 99-195.

Shara, Ron, 1974, "Lakes Drained - Was That Public Water," Minneapolis Tribune, Sunday, October 13, 1974, p. 1f.

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